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# Competition or joint working of railways and roadways in France, (1)

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We have previously reported upon the question of the competition and cooperation of railway and road transport in France, to the World Road Transport Congress (Rome Session, 1928), and the XIth Railway Congress (Madrid Session, 1930), in which reports we laid especial stress upon the role played by the French Public Works Department in supervising the experiments in co-ordination made by the main line railways.

The object of the present communication is to bring to notice the progress made in this direction since the Madrid Session (1930).

In their complete and interesting reports on Question XI of the present Session, drawn up by Mr. Edwin C. Cox for America, Great Britain, its Dominions and Colonies, China, and Japan (2), and by Messrs. F. P. VILLAMIL and d'OCON CORTES for all other countries (3), the Reporters, it will be found, have recommended, in their summary, that at the point at which legislative influence to lessen competition ends, the direct action of the railway administrations to seek all possible means of co-ordination with the road transport services commences. As a matter of fact, in the short time that has elapsed since the Madrid Session, the need for more complete co-ordination and the suppression of all ruinous competition in inland transport has been recognised by the public in whose hands, in the end, resides the future prosperity not only of transport but also of the countries themselves.

The application of this principle has been the more called for in France, as up to the present French legislation on public road motor transport is less advanced than in some other countries, as for example in Great Britain, Switzerland, and Belgium. Certain deliberative organisations have passed significant resolutions on this matter. As an example we may quote the resolution passed in June 1932 by the « Office de Transport du Sud-Est » (South Eastern

(1) Paper presented by the Author as an appendix to the reports published on Question XI of the Agenda of the Cairo Congress : *Competition between or joint working of railways and airways or railways and roadways. — An investigation from the technical, commercial and contractual points of view.*

(2) *Bulletin of the Railway Congress,* May 1932, p. 729.

(3) *Bulletin of the Railway Congress,* November 1932, p. 2113.

Area Transport Office) in which all the Chambers of Commerce of the South East of France are grouped, i. e. an area served by the Paris-Lyons and Mediterranean Railway chiefly, and also by the Paris-Orleans and the Midi Railways. This resolution which is in entire agreement with the conclusions of the reports mentioned above, is as follows :

The Transport Office of the Chambers of Commerce and Agriculture of the South East of France,

Considering that in the interest of the Public Finances and the National Economy it is desirable to modify as soon as possible the system of control of the railways so as to give them more adaptability and liberty, and taking into account the present circumstances and especially the position resulting from road competition ;

Considering that it is desirable to preserve the advantages resulting from the development of public road motor services, but that these, as operated at the present time, do not give the desired guarantees of regularity nor of safety for passenger and goods traffic ;

Considering that the roads were not built to deal with the present intense traffic and that this traffic appears likely to develop still further ;

Considering that it is desirable, in order to establish equilibrium between the railways and the public road services, not to impede the development of the latter but to subject them like the railways to certain obligations ;

Resolves that :

The system of control of the railways be modified so as to leave them more liberty and adaptability ;

The public road services (passengers and goods) be subjected also to a contractual control requiring the express assent of the Government beforehand, with regulations laying down exactly their obligations and particularly as regards safety, regularity, publication of rates, financial guarantees such as insurance, deposits, and other various requirements.

**New legislation under consideration.**

On the other hand, a demand was made that the new *Road Code* which is to replace and modify the Decree of the 31 December 1922 and the decrees issued subsequently, and which is now under consideration by the State Council, should be completed by a definite and up to date control of the public road services. This was not intended to hinder in any way the free development of the automobile industry but was to limit as much as possible the shortcomings of the staff, failures of material, and abnormal wear of the highways and other roads. We must therefore look forward to a much more effectual control by the Public Works Department over road transport and in particular supervision by the Inspectors of Working Conditions over the staff (hours of duty and aptitude), by the Mines Department over the rolling stock (loading gauges, maximum power, traillers, safety fittings, maintenance), by the road police (overloads, speeds, dimensions of vehicles, routes, etc.), and a commercial control (solvency, insurance, third party claims).

We have consequently to conciliate at one and the same time the competition and the progress this brings with it, with the technical and commercial guarantees to be insisted upon in the case of every public transport service, and with the need for safeguarding the economic equilibrium.

The principle of the necessity of obtaining an authorisation to operate a joint transport service has therefore to be admitted. This principle — it is not without value to look for the legal basis thereof — appears to rest on the idea that the road is not made to be in itself the object of an industrial under taking : the road exists for the public good, for individual purposes (pleasure, trade, industry) but is not left to the free disposal of persons or companies who would work it directly and for

itself. It is built and maintained by the administrative collectivities, who own it and who have the right to stop it being used in any way contrary to its true purpose and the public interest. The State Council stressed this idea of public interest in its decision of the 29 January 1932 (Antibois Omnibuses versus the City of Cannes).

This principle laid down, the resulting consequence is that the competent authorities are required not only to see that the contractual monopoly they have granted to joint public transport services is strictly respected, — this they are bound to do —, but also, outside any case of monopoly, to arrange in the best interests of the public the conditions of working joint transport services organised with their express or tacit consent. The sole limit to be imposed is that no misuse of power or abuse of law be committed (such as the case in which for example excessively and uselessly severe operating conditions should be imposed).

In brief the above shows that the qualified authorities in France have the right to prohibit, in the public interest, independent undertakings which have been set up without authorisation nor regulation or which it is proposed to start.

This public interest may be found in the case of a public service already organised, in abuses of competition, in the needs or convenience of traffic and, in general, in the correct use of the road system.

These are the principles which ought to be kept in the foreground during the drawing up of the new French legislation at the present time under preparation by the Administrations of the Public Works, Mines, Commerce and Labour Departments.

A bill sponsored by Mr. Leon Barety, regulating joint road transport services and based on similar principles to those ennunciated above, was adopted by the Chamber of Deputies (sitting of the 22 February 1928) and will shortly be submitted to the Senate.

Most of the requirements of this projected law are not applicable, however, to services organised under the control and responsibility of the main line railways, provided that such services, which moreover remain subject to the prescriptions of the decree of the 31 December 1922 and those which completed or will complete it (*Road Code*), have been approved by the Minister of Public Works.

### Ministerial circular of the 26 november 1931.

The point of view of the Government as regards competition of public road services with the railways has, moreover, been clearly laid down by the circular of the Minister of Public Works to the Prefects, dated the 26 November 1931.

This circular includes in particular the following considerations :

The working of the main line railway companies at the present time shows a deficit, and this situation is due in part to the loss of traffic due to road motor transport.

In accordance with the convention of 1921 which regulates the operation of railways of general interest, the equilibrium between the receipts and expenses should be realised by means of the rates, i. e. if there is a deficit the rates ought to be increased.

It is therefore the users who support in actual fact the loss of receipts.

Undoubtedly, the activity of any competition which, provided that it only operates with its own resources, can constitute a progress, ought not to be limited by arbitrary means. But the play of such competition should not be stinted by aiding it by subsidies from the public purse.

The failure to respect this elementary rule is exactly the same as paying for making a deficit which is to be made good afterwards.

The public authorities have the duty

of co-ordinating the different means of transport, of arbitrating between the legitimate interests of one and the other without unjustly favouring either, but also without forgetting that the railway is a public service essential to the life of the nation and that the latter, through the users, bears the costs.

The Government attaches the greatest importance to maintaining a just equilibrium between the different methods of transport.

One of the first measures necessary, therefore, is not to subsidise from the public funds road motor services which compete with the railway.

Besides, the Public Works Administration considers very carefully schemes put forward by the main line railways for setting up road motor services, to be operated either by themselves or by a subsidiary company, and only approve them if they are not likely to compete with light railways or subsidised road motor services.

In order to come to a decision, based on complete knowledge of the matter, when demands for subsidies are put forward by road motor services, which might be detrimental to railway traffic, it is essential that the Prefects carry out the enquiries prescribed by the ministerial circulars of the 21 July, 1924 and 22 November, 1927.

When no subsidy is asked from the public authorities the public road transport undertakings can organise their companies under the condition of having made a declaration to the Prefect who will deliver authority to carry out the service and lay down, by decree, the points at which vehicles can stand.

The stopping and parking points should be fixed after careful study, to meet the needs of the districts to be served and in such a way as not to favour the road motor service to the detriment of other methods of transport, and particularly by the railway.

During the operation of the service, care must be taken to see that the stopping points are scrupulously observed by the contractors.

**Conditions of operation of lines with slight traffic.**

In addition, the necessity has already been recognised of making the conditions of operation of the railways more flexible. For this purpose, the French Government tabled the 19 November 1931 a proposed law according to the terms of which the Minister of Public Works would be authorised, in agreement with the French main line railways, and subject to the opinion of the Supreme Railway Council, as regards lines with little traffic :

1. To withdraw the stipulations of the Conventions of 1883, which impose, for example, a minimum number of trains to be run each day on lines with very light traffic;

2. To modify certain articles of the requirements (number of classes of carriages, rates, composition of trains, free conveyance of luggage, period of publication and application of the rates, conditions of transport, times for delivery, conveyance of soldiers and naval ratings, postal transports, conveyance of prisoners), which impose expenditure and requirements hardly justified for the less important light railways;

3. By derogation from Article 4 of the basic railway law of the 15 July 1845, to give authority to do away with fencings or gates when crossing roads, as regards lines which, in future, will be run over by rail motor coaches or similar vehicles able to stop under the same conditions as a motor car on the road.

To sum, it is a question of abolishing the administrative requirements no longer justified by essential benefits to the users, and which prevent the modernisation of the operating services on the small lines.

Among these secondary lines with little traffic, must be included, in a first

group, those on which the passenger and goods traffic is extremely small, practically inexistant, and those on which the passenger traffic, while very small, can be worked by rail motor omnibuses, but the goods traffic over which could not be carried by ordinary lorries, and on which consequently goods trains must continue to be run. The extent of these lines has been estimated at about 4 000 kilometres (2 500 miles), that is almost one tenth of the whole of the main line railways in France [43 000 km. (26 720 miles)].

Independently of these classes of lines with very little traffic, on a large number of other lines simplified operating methods could be introduced, such as, in the case of passenger traffic, a reduction in the number of trains, the simplification of their operation, their replacement by rail motor buses and, in the case of goods traffic, improvements in the organisation of the stations, etc. As a whole, certain railways consider that a method of operation simplified in this way could be applied to more than one third of their lines.

The first tests were carried out on light railways. As from 1928, many reductions in classifications of lines have taken place, and road motor services substituted wholly or partly for the railway.

In the case of main line railways, many experiments have been carried out either to replace trains by road motor services, or by using rail motor cars, or by experiments with simplified operating methods.

The Public Works Administration has, for example, authorised provisionally a certain number of public road motor services to replace trains on all the railway systems and in many different districts.

Up to the present these substitute road motor services have been exploited according to three main methods :

*a)* Direct working by a subsidiary company of the railway;

*b)* Working rented to a third party, with or without premium, with or without guarantee;

*c)* Concession, to a third party, of the agency and the inherent advantages, in return for a small payment.

This idea of the future simplified operation of lines with little traffic has been translated into fact in a particular case, during the investigation into projected new lines on the French Est Railway, where provision has been made for the intermediate stations of the line not to be open to passenger traffic and only for goods traffic when dealing with full wagon loads.

**Rates.**

The question of rates is certainly more difficult to solve. It is necessary that the present system, established under monoply conditions and the working of which is now upset by competition, should be progressively adapted to commercial needs.

The French Railways are very anxious to be authorised to operate their systems according to the same methods as the competing road motor undertakings, i.e. as real industrial undertakings, according to the cost of each kind of transport, especially for passenger traffic and fast goods traffic. But a reform of this kind, however logical, cannot be carried out without some disadvantages affecting the general economic position. Moreover it could only be realised very slowly in order not to upset commercial, industrial and agricultural interests.

It appears necessary therefore, in France at least, in order to obtain a relative equilibrium between the different methods of transport, and in order that the users should not lose the advantages and guarantees to which they have been accustomed up to the present, that the Public Works Depart-

ment continue to regulate the rates of the railway, but under a more flexible form, in order to speed up the transactions, and that it sets up a similar regulation for road rates.

### Distribution of the traffic.

As regards the distribution of traffic between rail and road, the question has often been raised as to how this can be done. It would be necessary to proceed according to place and circumstance, by voluntary cooperation between the railway administrations and the road carriers, by participation of the railways, from the technical and financial points of view, in the working of the road undertakings, or finally, in default of this, by forcing the different transport undertakings into a scheme of coordination adopted by the public authorities, after consultation with the users. But as collaboration when spontaneous is much more desirable than when forced, it is to be hoped that the rail and road carriers will be able to come to an understanding to facilitate this important reform.

It is with this object that in 1932, at the initiative of the main line railways, a « Committee of Enquiry into the Coordination of Means of Transport » was set up on which were represented, in addition to the railways, the large road transport undertakings, the users (1) the motor vehicle builders, and the collecting agencies. It is to be hoped that the opinions and suggestions unanimously adopted by this Committee, will make the task of the Administrations and Public Authorities easier when studying the future system of control of transport and especially the distribution of traffic between the different methods.

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(1) Among the most qualified representatives of the users mention must be made of the « Central Rail and Road Office », a very active organisation which has collected much important information on the transport problem.

### Improvement in the operating conditions of the railways.

While awaiting the new legislative arrangements required for a general reform of transport, the French main line railways have been obliged to improve even now in an appreciable manner their present operating methods, particularly as concerns the rapid conveyance of parcels and the connection between the rail and road services.

Examples may be quoted : the reduction of the time of conveyance, organisation of parcels trains at higher speed, the institution of ordinary goods traffic with guaranteed delivery date, express parcels, constant revision of the rates including the introduction of contract rates and collecting rates, the setting up of cartage services by motor vans and lorries for handling goods from door to door, etc., and finally the development of auxiliary or subsidiary companies for road traffic set up as from 1928.

### Subsidiary road motor companies.

Since that period, several of these companies were in regular work and the number of services has been increased since, so that it is now possible to sketch in on broad lines the general organisation of these companies, their relations with the railways on which they depend. and with the public, as well as their practical efficiency.

1. *General organisation.* — The subsidiary companies have been set up to complete the railways by a more flexible organisation which would enable them not only to meet road motor competition, but also to develop the road traffic by serving the regions run through in a more complete and more economic way by a better adaptation of the equipment to the object to be attained. Thus the Government, far from laying down, especially at the outset, a uniform organisation, has left to each of the railway companies, the maximum amount

of initiative compatible with the general interest, and this explains the diversity of the combinations considered.

The principle most frequently adopted is the operation of the road motor services by the subsidiary company itself, with the exception, however, of those which, being isolated, would be too costly for a company of a certain importance and in this special case the subsidiary company makes the necessary arrangement with a local contractor who can operate at lower cost; this is the service known as *indirect*, in opposition to the *direct* service carried out by the company.

On the other hand, the subsidiary company of the Paris-Lyons and Mediterranean Railway does not operate on its own; its function is to study the organisation of each service to be set up, to discuss the various conditions with the contractor it has called in, and to supervise the carrying out of the service.

The duties carried out by the subsidiary companies vary :

1. *Replacement of trains.* — On secondary lines with little traffic, the trains which were run at a loss have been replaced by passenger rail car services which give the same service, but at lower cost. On some of these lines, all the passenger trains have been suppressed under these conditions, a regular or special goods train assuring the slow goods traffic as well as full wagon loads of fast traffic.

Finally on a small number of these secondary lines of short length, motor lorries cover the transport of goods from or to a central station, and carry out the transport from door to door within a certain area.

The substitution of motor cars for one or several passenger trains is sometimes carried out on main lines, but only over a short section, either permanently or during the season of little traffic, where this solution enables a useful connection to be preserved although insufficient to justify the cost of running trains. In this last class can be put some fast services which could not be carried out equally well by the trains between two localities situated on different lines.

1. *Connecting or feeder services to the railway.* — Whereas the preceding uses have had the object above all of making it possible to reduce the operating costs, these latter come exactly within the proper field of the subsidiary companies and consist in seeking traffic at points to which the railway cannot go. The object of these services is in fact, in the case of both passenger and goods, to serve either a given locality or a group of localities some distance from the railway and to collect there the traffic in order to bring it to a suitably selected centre station.

3. *Tourist services.* — These were the first road motor services which the French railways organised well before the setting up of the subsidiary companies; they were confided to individual contractors. According to the railway and according to the importance of the services, these continue to be operated as previously, or are worked under the subsidiary company, either by itself, or by a contractor selected by it.

The object of these services is to facilitate the visit to a tourist district, to convey thereto a larger number of passengers, who make use of the railway for the outward and return journey.

2. *Relationship between the railways and the subsidiary companies as regards the carrying out of the service.* — The first railways who set up subsidiary companies entered into general agreements stipulating the conditions to be observed by all the services to be set up as regards the operating staff, the equipment, the question of reciprocal responsibility, insurances, etc., and, in addition for each case, a second particular agreement referring to the first and containing the special conditions,

such as : route, points served, timetables, rates, subsidies or guarantees of the railway in certain particular cases or, if need be, money paid by the railway to have the service carried out, for example when the total receipts come to the railway (which is the most general case when trains are replaced).

Other systems are satisfied with entering into one agreement for each service, containing the clauses of the two agreements mentioned above.

Finally the Paris-Orleans and the Alsace-Lorraine Railways have laid down, for each case, a proper specification with rates; and only insert in each particular agreement for each service the particular requirements which could not be included in the general specification, or the derogations that have been recognised as necessary.

**Relations with the public.**

The most important indications given from this point of view are those relating to the rates.

1. *Replacement of trains.* — Two cases should be recognised :

The first concerns trains known as contractual, which the railway is obliged to run, according to the terms of the Agreements with the State (3 trains in each direction).

The railway rates are applicable only when the passenger has bought his ticket at the station; otherwise he is subject to the special omnibus rate, generally 0.30 fr. per km. (0.48 fr. per mile).

The French Midi Railway is the only exception, as in all cases the motor bus rates are applied : 0.25 fr. or 0.30 fr. per km. (0.40 or 0.48 fr. per mile) according to the lines.

For all other (non contractual) trains which are replaced by road motor buses, the special rate for this method of transport is applied; passengers with railway tickets from another section pay, over the distance travelled by road motor service, the supplement corresponding to the difference between the 3rd class railway fare (0.20 fr.) and the motor bus fare (0.25 or 0.30 fr. per kilometre, according to the railway).

2. *Other services.* — The rates are determined for each service, according to its nature and its importance.

**Results obtained.**

The first subsidiary companies set up have only been in existence for a short time (less than 5 years). Nonetheless if we except certain unsuccessful tests which were unavoidable, especially at the start, it has been possible, in the case of other than tourist services, to continue to work, under better conditions, services that the necessity for reducing expenditure would have made it impossible to maintain at the present time; in addition, on certain sections on which losses were being incurred, the operating costs have been reduced in appreciable proportions. In addition the few road goods services organised by the different railways have made it possible so far, if not to reduce very considerably the corresponding expenditure, at least to deal with certain particular traffic more effectively.

Finally the feeder services have generally given good results from the point of view of railway traffic.

Until a proved technical solution makes it possible to provide lines carrying little traffic with a system of locomotion (rail motor coach or rail motor bus) by which the equipment used can be made proportional to the traffic to be worked, the road motor can render appreciable services to the public as well as to the railway and the subsidiary companies of the railways form one of the methods to be used, on the condition of course that their manager takes the double care of giving new

facilities to the public and avoiding all non-productive expenditure.

**Containers.**

The French railways and the Government have also considered the method of improving the conditions of transport and of obtaining liaison between rail and road by the use of containers.

The container is certainly a simple and economical tool to extend as it were the railway and to take the wagon, or at least part of the body of the wagon from the door of the consignor to that of the consignee. It simplifies the rates, the bookkeeping, the dispatching and the delivery of the goods; it does away with intermediate handling, facilitates transhipment, simplifies packing. It makes it possible to transport goods throughout the journey without breaking load.

However, containers are still little used in France, except on the Nord and the Paris-Lyon and Mediterranean Railways, where they are beginning to be used, on the first for traffic towards England and Switzerland, and on the second for dealing with Algerian early fruits and vegetables.

In the beginning, up to 1930, the railway systems did not supply the containers themselves, and laid down the conditions to which were to conform the containers, which were supplied by the users. The latter protested against these requirements and pointed out that, like the wagons, the containers should be supplied by the railway administrations, who are called upon to profit to the largest extent by the advantages resulting from their use. These complaints, supported by the Government, have been finally accepted by the railways, who have shown themselves willing to supply the containers themselves and to hire them to the users.

Standardised types of containers are being considered, suitable both for railway, road and maritime transport, and capable, when empty, of taking up a minimum of space. The impulse given to these investigations by the International Chamber of Commerce and by the Railway Systems, in agreement with the Motor Industry, makes possible the hope of the introduction within a short time, of several types of standard containers capable of developing the use of this equipment for increasing numbers of classes of goods.

**Conclusions.**

To sum up, investigation into the competition between rail and road, in France as in other countries, leads the responsible authorities to consider a reorganisation of public transport necessary in order to safeguard the national economy.

In order to take into account the technical progress acquired already and the profound modifications of the bases of the rates system, the national economy requires, not the strengthening of the administrative requirements imposed on the railways nor the aggravation of the fiscal charges already borne by road transport, but greater flexibility in the operating methods of the railways, the reform of a system of rates based on a monopoly no longer existing, a liberal but efficient regulation of road transport in the interest of the users, and a judicial distribution of the traffic according to a rational plan of co-ordination approved or imposed by the public authorities after careful study, in full accord with the representatives of the different means of transport and the different classes of user.

*Paris, 28 November 1932.*

| 621. 13, 621. 335 & 621. 43 |

# Railway traction [1].

(*The Engineer.*)

## I. — Railway traction by steam power,

by Sir SEYMOUR B. TRITTON, K. B. E.

It is stated in many quarters that the steam locomotive for railway traction is dead, or will shortly become obsolete. Its newer rivals will produce reasons for its early demise, and their case will be heard with interest, but, in spite of certain obvious disadvantages, the steam locomotive is still holding its own, and the splendid records recently set up by our British railways are concrete evidence of its vitality. The remark is often heard that the speed of trains hauled by steam locomotives recently recorded is no greater than it was many years ago, and instances of high-speed runs are quoted in proof of this contention; but the greatly increased weight of the luxury trains now in use, with their dining and buffet cars, etc., and the long-distance runs made without stop, are often ignored; when taken into consideration it is clear that the present work done by the steam locomotive quite exceeds all previous performances.

Under the stress of rivalry and modern conditions probably greater advances have been made during the last few years than formerly. The details of these improvements and inventions have been so exhaustively dealt with by the technical Press that it is almost impossible for the author to introduce any novel suggestions. The object of the papers submitted to your Association is to promote discussion, so the author makes no apology for repeating much that has already been said, in the hope that the discussion may break some new ground. Although this is the British Association for the Advancement of Science, it has world-wide connections, but the author has confined his remarks chiefly to steam traction on British railways.

The general design of the steam locomotive has really been little altered since the early days of railways. This is due, it is considered, to the expansive use of steam, which enables it to be applied direct from the cylinders to the driving wheels. Direct drive from the cylinders to the driving wheels is still universal practice, and holds sway due to its inherent advantage of simplicity, mechanical efficiency and flexibility over a wide range of speeds. Such a drive is only possible when using an expansive medium such as steam from a boiler of sufficient capacity. It is in direct contrast to other forms of propulsion, in which power is obtained from a high-speed engine, with a reduction gear of some form to transmit power to the driving wheels. Every possible arrangement of variable gear mechanisms has been experimented with, as well as hydraulic, pneumatic and electrical transmissions, for this purpose. Examples which will at once occur to you are the marine turbine with geared propeller propulsion, the road motor car with its gear-box, and, for the lighter types of railway work, the well-known Sentinel rail car.

Whether the development of the high-powered main line steam locomotive will eventually be forced in this direction it would be difficult to predict, but until the principle has become a practical and paying proposition for main line work, the attraction of the simple « direct-

(1) Abstracts of papers presented to Section G of the British Association for the Advancement of Science at the meeting held at York, on the 5th September 1932. — Short account of the discussion.

action » drive of the present locomotive, with its expansive and cushioned steam impulse, still holds its own. The steam locomotive engineer will always enthusiastically uphold this expansive use of steam when comparing it with the « explosive » energy from which its internal combustion rivals obtain their power. An interesting example, however, of an ingenious design to combine the two systems is to be seen in the famous Kitson-Still engine. The engine is double-acting, with internal combustion at one end of the cylinder and steam at the other end, through which the piston-rod works. The water in the jacket is in connection with the boiler, and the excess heat from products of combustion assists in the production of steam in the boiler. The boiler is primarily heated by oil burners, and the steam generated is used for starting the engine. This unique locomotive, therefore, provides the combination of internal combustion and steam power, internal combustion for continuous work, and steam for starting, for overload, and for auxiliaries such as brakes, train heating, etc.

The disadvantages with which the steam locomotive has to contend when comparing it with its oil and electric rivals are obvious, but they will bear repetition. There is the wasteful procedure of producing steam by burning coal in the fire-box, with all its losses; the great expenditure on the conveyance and storage of coal; the cleaning of ashes and clinker; the enormous amount of water required (in spite of pick-up apparatus) and the hauling of its deadweight, together with the coal on the tender; the heavy expenditure on boiler repairs (especially with bad water) and the standby losses of the locomotive when not actually performing work.

This is a coal-producing country, and cheap coal was the cause of the genesis of the railways here; and so long as coal can be obtained at a reasonable price railway engineers will strive to use it in spite of its drawbacks. The Diesel engine has to use imported oil, and for electric traction, except where water power is available, coal is used to provide the power. The attraction of oil fuel for steam raising in the locomotive has long been before the locomotive engineer, and in countries where oil is cheap and coal is dear it is, of course, in use. In this country, for the reasons already mentioned, it is not in evidence, but during the last few years the whole aspect of the import of oil fuel, its marketing and distribution has so materially altered (witness the enormous quantities consumed by the Navy and the Atlantic liners), that, in the opinion of the author, the possibilities of its use on our railways cannot be altogether ignored. The cost of adapting steam locomotives would be great, but not insuperable, if the price were sufficiently low, and some security of cost could be obtained. There is also the possibility of pulverised coal, which is being so successfully used, both on board ship and in electric power stations.

The author was privileged to report on the earlier experiments made with oil fuel on the then Great Eastern Railway. A saucer-shaped fire was formed of chalk and coal, with which the run was commenced, the oil being subsequently switched on for the main portion of the journey, and the coal fire restored before reaching the destination, the idea being to enable the engine to stand by without injury to the boiler by cooling down before the return journey. The arrangement worked well, but was discontinued owing to the rising cost of the oil fuel. He was also present at, and reported on, the pulverised fuel experiments on certain locomotives on the then Midland Railway, the coal being pulverised by mechanism on the tender and fed to the fire-box under pressure. Much advance has been made since these experiments, and we have recently had brought to our notice the successful use of colloidal fuel, the mixture of coal and oil, which has

hitherto baffled the ingenuity of chemists and engineers.

The author has referred in the above remarks to imported oil, but the possibilities of British oil fuel cannot be ignored. The following quotation from a letter in the technical Press reads: « There is no subject that has caused or is still causing more interest and criticism than the well-known « oil from coal subject ». The world seems to be passing through the coal-burning to an oil-burning age, and the coal pits will eventually be selling not coal but gas, smokeless fuel and oil ».

The author makes no excuse for dwelling on the question of fuel for steam raising, because the development of the steam locomotive, and the physical endurance of the human element, seem to have almost reached their culmination with coal fuel as at present used, and mechanical stokers have not yet found favour, in this country, at any rate. In this connection, improved springing and more comfortable riding of the machine is indirectly a factor which cannot be ignored if the long non-stop runs now being made are to be successfully continued. It might well be that with the use of one of the other fuels mentioned it would be possible to design still more powerful steam locomotives within the restricted loading gauge of this country without increasing the permissible axleload.

Here it may be permissible to digress for a moment to emphasise one reason at any rate which has handicapped the development of the steam locomotive in this country, namely, the restricted loading gauge of our railways. By loading gauge is meant the maximum and minimum dimensions which a locomotive must pass if it is to clear fixed structures, such as tunnels, platforms, etc. This country was the first to build railways, and it is only naturel that the dimensions which at that time were considered generous should be quite inadequate for present-day requirements. This is especially noticeable when we come to the design of the boiler, and accounts for the practical disappearance of the chimney, which often puzzles the traveller.

A further difficulty is the weight of the locomotive, and more especially the distribution of it, which has gradually increased, calling for costly bridge renewals and heavier rails. The normal axleload, by which is meant the load measured at the contact of the wheel with the rail, in this country is about 20 to 21 tons, but engines with 22 1/2 tons axleload are running in India, and one for 28 tons has actually been designed. In America this latter figure is actually in use. But the static axleload might be increased, certainly so far as bridges are concerned, if the latest research on the subject of impact on bridges is given effect to. With this is associated the hammer blow of the wheels on the bridges and rails, a subject which is stressed by the exponents of electric transmission when comparing the steam with the electric locomotive, and the latter's admittedly more even torque and better acceleration. The balancing of steam locomotives has not in the past received the attention which its importance deserved, but there is a movement on foot to investigate the effect on the running of the locomotive by reducing the proportion of the reciprocating parts which it has hitherto been considered necessary to balance. For any reduction obtained in the hammer blow it is reasonable to contemplate a corresponding increase in the static axleload distributed over the driving axles of a locomotive designed to run on existing rails, which would be a boon to the designer, and prove another direction in which the power of the locomotive might be increased within its existing restrictions.

The ultimate aim, apart from increased power and speed, is obviously the reduction of fuel consumption, and the best brains of the engineering profession have concentrated on this, the use and evolution of the superheater being one of the

most important improvements now generally adopted. Mr. Gresley, in commenting on the author's presidential address to the Institution of Locomotive Engineers, however, made special reference to the need for greater economy in steam distribution. Without this, the economy claimed for the high pressures now being used, and the still higher pressures being experimented with, may be largely discounted. The economical distribution of steam by means of improved valve gear has been engaging the attention of designers, especially of late, and the latest forms of poppet gear, as illustrated in the Lentz and Caprotti types, are showing considerable economy over the Walschaerts gear in general use. The engineer who is not directly associated with steam power transmission is inclined to be critical when reviewing the coal consumption of the steam locomotive. The most modern and efficient power-house plant represents the maximum economy obtained in converting coal into energy at about 1 kw.-h. per pound of coal of high calorific value and with a high load factor. It is difficult to make any real comparison with the steam locomotive on this basis, and naturally it is not feasible to carry about economisers and condensing apparatus of the size and efficiency found in an electric power station. But it must not be forgotten that experiments have been made in this direction. More than one locomotive has been built where the steam turbine is the prime mover, and an elaborate arrangement of condensers and fans is employed to deal with the large volume of exhaust steam. This problem of condensing the exhaust steam, whilst comparatively easy at sea, and on land where ample water is available, proved to be most difficult to solve in the steam locomotive of this type. Notable examples are the Ljungström, the Maffei, and the Ramsay. In the Ljungström and the Maffei, the steam turbine is connected by reduction gearing to the driving wheels, and in the Ramsay the turbine drives an electric generator supplying current to a motor driving a jackshaft coupled to the wheels. There is no doubt that these locomotives show considerable reduction in coal and water consumption, but so far it would appear that the advantages obtained have not outbalanced the disadvantages of high initial cost and upkeep.

It is in the boiler, however, that the greatest change is coming about. In spite of the reduced consumption above referred to, the demand is yet for more steam, and the use of higher pressures to promote economy.

It would appear that a steam pressure of 250 lb. per square inch is about the limit that can be used in a locomotive boiler of the present type, whose size and weight have reached their limits and must lead to a radical change in design.

There are several novel departures in high-pressure design for steam locomotive boilers, which may roughly be divided into two types — that which may be termed the three-stage, or, perhaps more happily, the multi-pressure boiler, and the water-tube boiler. There are several variations of each, and detailed descriptions would not come within the scope of this paper, but the Schmidt-Henschel, which is being tested on the London, Midland and Scottish Railway, is, perhaps, the most interesting of the multi-pressure boilers. In this boiler, steam is raised in a high-pressure drum by means of a closed circuit of tubes and headers (forming a firebox) and an evaporating coil in the high-pressure drum, the steam being generated by indirect heat. This transfer process is, of course, not a new one, as it is in use for heating and cooking boilers, or cauldrons, but it has the advantage for high-pressure boilers that distilled water can be used in the coils, which does not suffer loss by evaporation, and the high-pressure drum, being fed with water from a low-pressure boiler section, and also not being in contact with the fire, is not liable to

form scale. Steam is maintained in the closed circuit at about 1400 lb. pressure, and raises the pressure in the high-pressure drum to about 900 lb. This steam is fed to the high-pressure cylinder, and the exhaust steam from this cylinder, supplemented by superheated steam from the low-pressure boiler heated by the flue gases, is taken to the low-pressure cylinders at about 250 lb. pressure.

The water-tube fire-box has been experimented with extensively in America, but the most interesting example of the water-tube boiler proper is that of the London and Nord-Eastern engine « No. 10000 ». In this locomotive, Mr. Gresley collaborated with Messrs. Yarrow, the well-known designers and builders of water-tube boilers for marine work, in evolving a water-tube boiler which could be successfully used for locomotive work. Such a boiler involved radical departures from marine and land practice. Perhaps the chief feature of this boiler is the long single steam drum which forms the back-bone of the boiler, is large enough to admit a man, and into which water tubes are expanded, and from which, also, the lower drums are suspended, special arrangements being made for expansion.

The pressure adopted is a more moderate one than that of the multi-pressure boilers already referred to, being 450 lb. per square inch. A detailed description of the ingenious arrangements to provide for expansion, and to prevent the formation of scale, and the stream-lining of the whole locomotive, cannot be given here, but has already been published.

No doubt modifications may be found necessary after further service, but this boiler has the great advantage of simplicity of construction, adaptability to modifications of heating and grate surface, and its application to the steam locomotive seems assured. The cost of maintenance, when applied to a new design, is often the measure of its success, and all indications point to a low cost of maintenance in a boiler of this type.

This *résumé* would not be complete without reference to the great improvements in the materials which can be used in the construction of the locomotive, although in this respect the steam locomotive cannot alone claim the benefit of them, as axles, tires, etc., are common to oil or electric locomotives, but the steam locomotive stands to benefit to a greater extent because of the use of special steels for boiler plates and tubes and steel connecting-rods weighing over 1 ton, which form such an important part of its design. We have seen, therefore, that the steam locomotive, restricted as it is in this country by the limited loading gauge and limited axleload, etc., is fulfilling the calls made upon it. Some of the present restrictions can be met by improved methods of balancing, especially in two-cylinder engines, permitting of higher axleloads, but if demands are still further increased, and further economies are to be obtained, the new designs of boilers with higher pressure, and the possible use of other or different forms of existing fuel seem the direction in which still further progress may be expected. Meanwhile, the steam locomotive in its simplest form, but with the latest improvements in detail, is fulfilling the demands made upon it, is handling the fastest and heaviest trains in use, and the demands of the user have so far been matched by the progress of the designer.

## II. — Oil traction.

Sir Henry Fowler made a statement of the present position of oil traction on railways, with necessary references to the historic side of the question, but without attempting to go into the details of the construction and working of oil transport, or to suggest definitely the position it would finally occupy on railways. In this paper Sir Henry recalls the view held by Sir Frederick Bramwell about fifty years ago, that the internal combustion engine would be the principal producer of power for all purposes before

this date. This was dealt with last year in the « Bramwell » lecture, which had constituted the presidential address to Section G by Sir Alfred Ewing (now President of the British Association). Although it is only comparatively recently that special attention has been paid to this method of traction, says Sir Henry, naturally it has received consideration since the petrol engine was developed by Daimler in 1887, and since Diesel brought out his heavy-oil engine in 1895. There were certain difficulties of adaptation, some of which are hardly solved at the present day. In 1905 he examined all the existing applications in Western and Southern Europe, but could not then report on any as being moderately satisfactory. In 1912, a large experimental locomotive was built for the German State Railways, the frame, etc., being suplied by the Borsig Company, and the 1000-H.P. Diesel being manufactured by the Sulzer Company, of Winterthur, Switzerland. The engine was started by compressed air carried in a large number of «bottles» on the vehicle. It is said to have been the first and only large oil locomotive with a direct drive. He had the opportunity of seeing it, and recognised early the difficulties likely to arise when it endeavoured to start with a load of any size.

Generally, one may say that the lack of flexibility of the internal combustion engine for railway traction was not at first generally recognised. Undoubtedly progress would have been more rapid had the demands of railway transport, both from an acceleration and gradient standpoint, been more carefully considered. In addition, the operating staff had been accustomed to being able to increase the ordinary load without serious consequences. Even up to quite recently, if not to-day, there has been a struggle between having an excess margin of power and the extra cost of providing for this margin.

There is, and always has been, something fascinating in the idea of employing an internal combustion engine for railway transport. Ease of starting up, the elimination of turning at a terminus, the small attention required, the removal of the necessity for providing water, and other points give to a self-contained unit great advantages. There are, however, certain disadvantages — and Sir Henry deals only with the oil engine because, although there are a considerable number of units driven by petrol engines in the United States, he feels that their use is not likely to increase, in view of the improvements of the oil engine.

The three main points to be considered are: 1. weight, 2. flexibility and the necessary transmission, and 3, the economic standpoint. If these three matters can all be solved satisfactorily together, there can be no question of the success of oil traction on railways.

With regard to weight, the early Diesel engines were built for stationary purposes, with heavy frames, cylinders, etc., and the same features were carried forward when they were applied to traction. The remedy for this weight was to increase the speed of revolution. That success in this direction has been achieved can be judged from the fact that the ill-fated airship « R-101 » was fitted with this type of engine. The increase of speed, however, entails some disadvantages, and it, and the desire to lighten all parts, have to be watched carefully in all designs.

The tractive effort is low on the level, but when running up an incline the percentage increase may be very great. Assuming that the tractive effort on the level is 15 lb. per ton (a fairly high figure), this will be about doubled by an up gradient of 1 in 150. With steam and electricity this can be met, at all events for a time, although perhaps by loss of speed. With an internal combustion engine, however, this is not so unless some type of variable transmission allows of an increase of torque. The

most generally successful device for this purpose is electrical transmission, and this would seem to be the only practical one at present for locomotives of any size. Unfortunately, however, it increases the weight of the equipment, often the space required, and in all cases makes the plant much more expensive.

Ordinary gears, such as epicyclic, clutch, or plate (disc) are suitable only for small powers. They are not, as a rule, expensive, and are simple; probably they will always be employed for small engines. Several gears of the hydraulic type have been or are being tried, but, again, usually for small powers. There are two systems which depend on the compression of air by means of a Diesel engine, and the utilisation of this air, mixed with steam or by itself, in cylinders. This type has not been fully tried out, although a locomotive in Germany has been running for some time. The Kitson-Still engine might be looked upon as coming under the category of this type, whilst the same claim might be made for its inclusion under the category of steam engines.

Coming to economic considerations, Sir Henry said that, as compared with a steam locomotive for main line working, an oil engine locomotive will cost about double. This means a heavy overhead charge for interest and depreciation. Undoubtedly the first cost is high. The fuel costs undoubtedly are low, but the cost of oil for lubrication is probably considerably higher than when using either steam or electric traction for the same unit. There is the ease of drive, and probably the same claims can be made for a « one-man » drive in this case as with electric traction. Maintenance and liability to casualties we know little of, but the latter, at all events, although they might be high at first, should finally fall as low as with either of the other types of traction. The ease with which an engine can be re-fueled should not be lost sight of. The high first cost remains, but, like the electric motor, the oil engine can practically run the clock round, and in this direction can offer advantages over the steam engine in some cases, although some steam shunting engines do work the clock round, whilst in other cases, especially in passenger work, the long daily hours are not required. Each case must be worked out for itself.

Sir Henry then goes on to deal with the work which has been done with oil traction on railways, in shunting engines, rail cars and main line locomotives. For shunting engines there seems considerable scope, for in many cases they are required to work for long hours each day, with the resulting spreading of overheads. Circumstances will dictate whether one or two men are required. There is a very large number of this type of machine in use, ranging from those equipped with engines of from 400 to 600 H.P. down to very small units. The latter are nearly always fitted with mechanical transmission. One wonders whether this could not be made even simpler of operation, were it of the selector or Wilson type. In some of the smaller goods yards in Germany, and, he believed, elsewhere, in cases where the work does not warrant the provision of a fairly large engine and a driver, a small Diesel-driven shunting engine, with mechanical transmission, is provided. One of the yard staff is responsible for driving this engine when it is required.

It is probable that the internal combustion engine was first used for railway work in rail cars. They were, however, usually under-powered. It is with them more than with the other two classes that the difficulty of varying loads arises. A small branch will perhaps be worked efficiently for five days a week with one vehicle. The sixth day, however, is market day, and the traffic is doubled or trebled. The provision of power to allow of extra vehicles being attached adds materially to first cost. Again, for such work the long hours of service,

which spread the overhead charges, are not often desired. This type of vehicle has been introduced on the Canadian National Railways, and it is interesting to note that the size of engine for the cars has increased. Many rail cars are used in the United States, but a large proportion use petrol. Denmark employs a considerable number, and Siam has many in service.

As to the main line locomotive, Sir Henry drew attention to an article published in *The Engineer* for the 29 January 1932, page 121, in which a list is given. He mentioned, however, that in addition to the Russian locomotives, one example is the Canadian National, in which, with two units coupled together, a horse power of 2660 is obtained. Of great interest, too, is the «mobile power-house» of the Buenos Aires Southern Railway, in which the power unit supplies the attached train with current. In nearly all cases, however, electric transmission is employed.

It seems somewhat strange that certain countries, where the water question is a serious one, have not carried out more experiments. The whole problem, concludes Sir Henry, is one of the most interesting that confronts the railway engineering world at present.

### III. — **Electric traction.**

Mr. F. Lydall, of Messrs. Merz and McLellan, consulting engineers, in a paper dealing with railway traction by electric power, confined himself to 1. propulsion by electrical energy transmitted to the trains from any source by track conductors, and 2. propulsion by self-contained power units in which the source of energy is a storage battery. Dealing with the relative advantages of these two systems, it is pointed out that under certain conditions the elimination of the track conductors by the use of batteries carried on the locomotives may be more important than the drawbacks arising from the capital cost of the battery system and the higher maintenance of the equipment, etc. Although for shunting and work in station yards, battery locomotives have been employed, little has been done with this system in the general field of railway working. An interesting development in this direction, however, has followed the recent invention by Dr. Drumm of a new type of traction battery which has the special characteristic that it can be charged and discharged at rates which are very high in relation to its size and weight. Thus, it is possible, in a partial or boosting charge of only 20 minutes duration, to store sufficient energy for an output of 2 watt-hours per pound of battery and to repeat the cycle of charge and discharge twenty times a day. This battery has been fitted to a two-coach train on the Great Southern Railways of Ireland, running a shuttle service between Dublin and Bray; but Mr. Lydall expresses the views that it is not likely that battery traction will supersede the present system of track conductors, and that with any form of battery at present available, this system of electric traction can have only a restricted field of application.

The main justification for the electrification of surface railways depends upon either:

*a*) its ability to provide a service of passenger trains so much more attractive in respect of frequency and average speed of running than would be practicable with steam operation that the increase in revenue is greater than the extra cost of working and the charges on the new capital ; or

*b*) the possibility of effecting sufficient reductions in the working expenses to provide a margin of profit after payment of interest and other charges on the additional capital required ; or

*c*) a combination of these two possibilities.

The first of these alternatives is generally applicable to suburban passenger

services, but as regards those electrifications for which the calculable justification depends upon the ability to secure sufficient reduction in working expenses to meet the annual charges in respect of the new capital expenditure and provide some surplus as an inducement to embark on the undertaking, the author gives a warning against attempting to draw up a generalised balance sheet on what might be called a theoretical basis. Each case has its own individuality and must be investigated in detail, not only as regards capital expenditure, but the possible savings to be made on each item of working expenses. The paper, therefore, discusses in some detail the three principal items which, together, make up about 75 % of the total of those working expenses which are affected by electrification, viz. : 1. locomotive fuel (or electric power); 2. wages of drivers and firemen; 3. locomotive repairs and maintenance.

Many detailed figures are given of consumption of coal and electric energy on certain sections of British railways, and the author's conclusion is that with the present price of coal, the question for Great Britain of whether there is any particular saving due to electrification under this particular item will depend upon the proportions of the different classes of traffic. If the volume of passenger traffic is small and there is much shunting, there will be a saving; if there is much passenger traffic and little shunting a saving cannot be expected. At the same time, any increase in the price of coal over present prices would modify the comparison in favour of electric working.

Dealing with the relative wages of drivers and firemen with coal and electric working, it is pointed out that there would be a considerable saving in this respect by reason of the general speeding up of all classes of traffic except express trains. Something might also be allowed in regard to the time for cleaning and preparing locomotives in the sheds. As an example in this connection, reference is made to the figures prepared by the London & North Eastern Railway officers for the report of Messrs. Merz and McLellan to the Weir Committee. For the whole of the services on the sections included in the company's investigation (King's Cross to Leeds, Nottingham to Lincoln and Boston, Doncaster to March, and certain lines in Lincolnshire), it was estimated there would be a saving in wages of 20 %, or £ 132 880 per annum. The possible savings due to the operation of one-man trains are also referred to and the likely objections to a general reduction of staff in this way on main line working are discussed. This point was considered by the Weir Committee, whose view was that instead of reducing the number of men employed the ultimate effect would be to employ more, inasmuch as any scheme of electrification would include a considerable intensification of suburban services which would also be favourable to the establishment of additional train-mileage in areas other than suburban.

In connection with locomotive repairs and maintenance, a number of figures are quoted from experience on electric railways in South Africa and India, and the claim is made that for any given scheme of electrification, the equivalent cost of locomotive maintenance should be less than half the corresponding cost under steam conditions, the correspondence implying not necessarily equal locomotive mileage, but an equal amount of work done. Experience has demonstrated that the mileage between heavy overhauls may be as much as 200 000 for electric locomotives, whereas the general practice is to send steam locomotives to the shops after less than half this mileage.

The paper also points to smaller, but nevertheless, important savings on other items after electrification, and also to the many incidental advantages, dealt

with in the Weir report, which cannot easily be assessed. Finally, the author suggests to the railway companies that whilst coal will continue to be used for the production of power for railway purposes, it would be in their interests to leave the utilisation of coal to the power undertakings and to take the electrical energy so provided. The question for railways is essentially the same as for large factories. No modern factory is operated with a separate prime mover — either steam or oil engine — for each unit of plant. On the contrary, individual machines or groups of machines are driven by the simplest, cheapest, and most efficient power units available, viz., by electric motors, the more complicated business of power production being left in other hands. This was a modern development now firmly established and it could hardly be doubted that in the near future it would be recognised as the most advantageous system for a large part of the railways of this country.

## Discussion.

Lieut.-Col. E. Kitson Clark, opening the debate and referring to the wear of rails, said he had always been interested in keeping the centre of gravity of rolling stock a little high; he considered that the centre of gravity on the Metropolitan Railway was getting very low indeed, and that that had a bad effect on the wear of the rails. A very great objection to the steam locomotive was the dirt caused in lighting up, and he asked if it were not possible to have some form of reservoir storage by means of which coal lighting up could be rendered more easy. Again, he asked why the Nicolson thermic syphon was not more widely used on locomotives. Locomotive boilers were inefficient in respect of steam area, and the giving-off surface for the steam was not as much as it might be. Why not, therefore, use the whole of the loading gauge, both in height and width, in order to get 15 % increased steam area, and an enormous increase of the area in which the bubbles of steam could rise from the water surface? Again, it was extraordinary that the expansion valve had rarely been used on locomotives, and he instanced a case in which the replacement of a boiler had been rendered unnecessary by the use of expansion valves. Another suggestion was that, in order to reduce radiation from the whole body of the machine, it should be enclosed in a box, which could be streamlined.

With regard to the use of electricity for traction, he emphasised the importance of the cost of conveying it to the points of usage, and pointed to the damage which might be done to the transmission lines in the case of war or civil commotion.

Referring to the Kitson-Still locomotive, he said it was a bold attempt to carry through something which was wanted. Electricity had its place, but was expensive, and it would be an advantage to anybody using oil engines to eliminate that and apply a method of transmission which was less expensive, and which did not require a special trade to look after it.

Professor Lomonossoff, who designed the first high-powered electric transmission locomotive built, said that the objective criterion for determining which form of traction was most suitable for given conditions was the total cost per ton-mile gross, including the amortisation of the capital. In his opinion, in the present state of engineering and statistical knowledge, this value is predeterminable and not less accurately than are the stresses in a bridge. He put forward equations by which this value could be determined, and plotted the results obtained.

Mr. C. H. Merz, discussing the expense of electrical propulsion, said that in certain directions it was the cheapest. The claim for electrical working under proper conditions rested largely on the great reduction of cost of maintenance of rol-

ling stock. It was interesting to consider other forms of transmission than electricity, from the internal combustion engine to the wheels, and if something practical could be developed on such lines it would enormously increase the suitability of the oil engine under certain conditions. But where traffic was dense, it was probable that electrical working would increase in this country.

Sir Josiah Stamp said that it would be bold to prognosticate for many years ahead the position in regard to fuel costs. The future of coal in this country was always likely to come into the middle of the political field, and the economic position as regards costs was uncertain. The cost of electricity, as delivered, was largely a function of total usage. Again, he wanted more knowledge of the relation between the period of physical durability of a machine and its obsolescence. Thirdly, he pointed out that American engineers were turning away from the inevitability of main line electric traction towards the extension of the possibilities of steam locomotives. In this country there were quite a number of advantages in the steam locomotive. There were the serious limitations of the loading gauge, and under the pressure of those limitations it was quite possible that further ingenuity would be displayed and discoveries made, particularly if the hammer-blow question were relieved. British railways were considerably reducing costs of maintenance per engine-mile, and increasing the distance between overhauls, whilst there were devices for rapid acceleration similar to that of electrical services, so that the steam engine was not quite so out of date as some people believed. On existing stock there was a greater range of speeds than before. Thousands of locomotives were now expected to achieve a regular high performance, but no one knew what that would lead to in the way of real technical knowledge about costs. Railways had, however, some inkling of the way in which the speeding up might itself give rise to economies which would offset any increased coal consumption due to attaining greater speeds.

Dr. W. L. Lowe-Brown, who dealt with suburban railway traction, said that where stations were close together a high rate of acceleration was essential for a rapid service, and that acceleration depended upon the gross weight of the train and the tractive effort. Though an enormous amount of concentrated attention had been paid to increasing the power, he submitted that the same amount of thought had not been devoted to reducing the gross weight. For every ton of passengers carried on the railway, the motive power had to accelerate about 8 tons of weight. In an eight-coach train, carrying, say, 640 passengers, or 40 tons of passengers, the total weight to be accelerated was between 300 and 400 tons. The omnibus had a gross weight of 3 tons per ton of passengers, whereas the railway train had from 8 to 10 tons. A cynic had said that when a part of a railway train proved too weak, the engineer made it heavier; whereas when part of an omnibus was found to be too weak, the maker looked for a stronger material. No doubt if the same attention were given to reducing the weights per passenger on a train as has been given to increasing the tractive effort, that discrepancy would be largely reduced.

Mr. J. M. Fay, discussing the use of the Drumm battery, urged that under certain conditions a locomotive using a battery which could be charged very quickly, was of very robust construction and had long life, could help in the ordinary electrification by taking over those portions of a line having a traffic density too low to justify, for economic reasons, ordinary continuous contact electrification. A 1-ton battery would provide the necessary energy for more than 300 000 ton-miles per year.

Mr. C. J. H. Trutch, discussing oil-electric locomotives, referred to some which

had averaged 150 000 miles, during which only one had required help. That was due to a short circuit in the electric equipment, and not to trouble with the engine. He had not yet found any transmission as satisfactory as the electric, and nothing appeared to have the prospect of being appreciably cheaper. The capital cost was not twice that of the steam locomotive. Further, he gave figures which indicated a saving of 43 % in the annual working costs as compared with steam locomotives, which was very much higher than the saving effected by electrification. For suburban traffic in this country, however, the conditions were such that electrification was indicated.

Wing-Commander T. R. Cave-Browne-Cave agreed that for suburban traffic, electrification was unquestionably the proper thing, but suggested that the proper solution of the main line traffic problem was a mobile power station feeding ordinary electric rolling stock; the power station would supply power as soon as the train ran off the electrified track at the terminals. His suggestion was somewhat similar to that put forward by Mr. Ricardo in another connection. The present practice, of having one or two large engines designed to meet very special requirements should not be continued, but ten or twelve heavy-oil engines, such as are being developed for road transport and made in such numbers that production was cheap, failures rare and overhaul rapid, should be used. They would be coupled to high-speed generators and would need no more attention than the omnibus engine gets. Failure of one of these units would scarcely influence the timing of the train, and its replacement by a complete spare could be effected in, perhaps, two hours in any running shed. That system gave one-man control and no physical exertion. Adhesion was due to the weight of the train, not that of the locomotive; the locomotive, therefore, could be as light as the machinery allowed. It was fair to assume that the weight of the engine would be about 10 lb. per H.P., and the dynamo about 20 lb. per H.P., *i.e.*, the power in electrical form for about 30 lb. per H.P., or 30 tons for 2000 H.P., which represented a weight immensely less than that which would have to be used for producing power in any other way. The advantages over steam locomotives would be quick acceleration at terminals and at most stops, quick turn-round, short overhauls, no more smoke and dirt than with electric power, no water to be used, and a great reduction of locomotive weight.

Mr. Fell suggested that the cost of an internal combustion engine main line locomotive would be about 2 1/2 times that of a steam locomotive. For our heaviest main line locomotives we should require about 2 000-H.P. oil engines to give a decent margin under all conditions. If one accepted electric transmission, the cost was about £8 per H.P. for transmission; that meant £16 000 before starting with the engine. The total cost would be about £13 per H.P., so that the locomotive would cost about £26 000, as against £10 500 for a steam locomotive to do the same duty. That appeared to rule out the use of heavy-oil engines for express passenger transport. Compression ignition locomotives of about 500 H.P. would seem to be suitable for branch lines.

Professor F. C. Lea said that the problem must be considered in connection with the fuel situation as a whole in this country, and emphasised the necessity for developing our own fuel supplies.

Sir Henry Fowler, in a brief reply to the discussion, said that the scheme described by Wing-Commander Cave-Brown-Cave was already used on a small scale on the New York Central Lines for local work.

Mr. Lydall, discussing the wear of rails on lines electrically operated, said it was frequently overlooked that the volume of traffic on such lines had increased very

greatly in this country, and he questioned whether the increase of wear of the rails was greater than the increase of ton-mileage passing over them. In many places in other countries where there had been main line electrification, the traffic had, in certain instances, been increased, but he believed that where it had not been increased the wear of the rails had not been increased. As to the cost of fuels in the future, it was reasonable to assume that the price of coal would not be reduced very materially; it might go up, in which case the advantage of electrification would be increased. With regard to obsolescence, he asked if there were really any advantages in early replacements. If the efficiency was maintained at nearly 100 % of the original, and the cost of maintenance was very small, there was no reason why early obsolescence should be insisted upon.

[ 621. 138.5 ]

# New procedure for setting locomotives frames and crosshead guides,

by Herr ILTGEN,

Direktor bei der Reichsbahn (German State Railways).

(From *Glasers Annalen*, 1932, Vol. 110, No. 1310.)

The present method of setting locomotive frames and crosshead guides in the repair shops of the German State Railways is as follows :

After levelling up the frame in the usual way, adjustable supports carrying longitudinal straightedges are placed in position on both sides so that the upper face of the straightedges coincides with the horizontal plane passing through the centre lines of the axles, which in the case of locomotives having horizontal cylinders coincides with the cylinder centre lines (1).

The horizontal position of the straightedges both longitudinally and transversely is checked with a spirit level.

The horizontal cylinder centre line plane is marked on both sides of each axlebox guide on the upper face of the horizontal straightedges.

A steel wire 0.3 mm. (0.0118 inch) in diameter is then stretched along the centre line of the cylinders, extended as far as the rear end of the frame (2).

End gauges of the same length are then interposed between the straightedges and the outside faces of the leading and trailing hornblocks, as these faces are not subject to wear, or in the case of bar frames between the straightedges and the frame itself, and the straightedges are then brought up to them.

If the straightedges are not parallel it will be necessary to ascertain in each case the position they will have to occupy to be parallel to each other, and also as far as practical to the centre line of the cylinders.

If necessary the leading and trailing horn cheeks must be machined to correspond with this position, or when bar frames are used, packing pieces must be fitted.

In order to arrive at the distances between the centre lines through the cylinders, and the driving axle, and between those through the driving axle and the coupled axles, the flat straightedges are marked off to the drawing dimensions, the distance between these marks corresponding to the above distances. The straightedge on the right hand side of the locomotive is applied in such a way that the scribed mark on the straightedge representing the cylinder centre line coincides with the actual centre line. The straightedge on the left hand side of the locomotive is then adjusted longitudinally until the edge of a try square covers the centre line of the driving axle marked on both straight-

(1) In some shops the straightedges are carried on fixed supports so that it is unnecessary to put the straightedges in place and then remove them for each operation. This method, however, involves the provision of fixed setting stands.

(2) For setting the crosshead guides, rigid graduated tubes centred in the steam cylinders are also used.

edges. The next step is to measure on the left hand side of the engine the difference between the centre line of the cylinder as marked on the straightedge and as it actually is.

In the event of this error exceeding the permissible tolerance [plus or minus 1 mm. (0.039 inch) for new locomotives and plus or minus 5 mm. (0.197 inch) for old ones] both longitudinal straightedges are adjusted uniformly either forward or backward until the centre lines of the cylinders are at the required distance from the centre of the driving axle, the tolerance allowed being taken into consideration.

If the displacement does not fall within the permissible tolerances for the centre lines of the cylinders and the distance of the horn cheeks from the centre line of the axle, the position of the cylinders must be corrected.

Marks by which the axle centre line can be located are made on both sides of the gaps in the frame from lines scribed on the straightedges representing the centre lines of the axles to the drawing dimensions.

After calculating the distance from the graduated edge of the straightedge to the centre line of the horn cheek, the centres of the bearings or journals are marked by pop marks from the graduated edges of the flat straightedges, but this time on the faces of the horn cheeks and wedges. The following standard dimensions are then checked by means of special measuring instruments :

*a*) Distance from the centre lines of the different axles to the corresponding faces of the horn cheeks and wedges. In making these measurements the above mentioned scribed lines on the flat straightedges are those representing the centre lines of the axles;

*b*) Distance from the centre line of the horn block to the faces of the cheeks and wedges. These measurements are made starting from the pop marks mentioned above on each horn cheek.

In the event of the limits of wear for the dimensions *a*) and *b*) being exceeded, the horn cheeks and wedges are either renewed, or alternatively built up to the drawing dimensions by welding. After being ground up, the horn cheeks are again checked over in the same manner, and the necessary dimensions taken for machining the axle box slides and boring the journal bearings.

The relative position of the centre lines of the cylinders to the centre line of the frame is checked by means of special measuring instruments, by determining at two points the distance from the outer edge of the straightedge to the 0.3 mm (0.0118 inch) diameter steel wire. Should the obliquity exceed the allowed amount, the position of the cylinders must be corrected.

The information so far collected on the above mentioned system of measuring shows that the use of long straightedges has the disadvantage that the measuring instruments do not remain as accurate as required; the straightedges are awkward to handle. The graduated edges are easily damaged in the shops. Through the ageing of the metal and the consequent displacement of the molecules, the straightedges get out of line. The result is errors in the spacings of the lines representing the drawing dimensions.

For these reasons, in 1927 Messrs. Zeiss, in collaboration with the German State Railways Headquarters and the Tempelhof repair shops evolved a new procedure based on optical principles obviating the use of long straightedges and try squares, and at the same time saving a considerable amount of time.

The longitudinal straightedges and the wire representing the centre line of the cylinders are replaced by the optical axis of a telescope which is centred in the cylinder. The distances between the centre lines of the axles, which hitherto have been measured by means of the lines on the longitudinal straightedges

are now determined by end gauges. The try square is replaced by a gauge set exactly at right angles to the optical axis of the telescope.

In figure 1, the telescope 1 consists of a rigid external tube 2 which carries the internal tube 3, housing the lenses. By means of two micrometer screws 4 and a ball joint 5 at the further end of the telescope, the inner tube can be adjusted in two planes at right angles to each other. The outer tube carries the end gauges 6 by which the telescope is automatically centred within the forward end of the cylinders. When the two micrometer screws 4 are set at zero the optical axis of the telescope coincides with the true centre line of the cylinder.

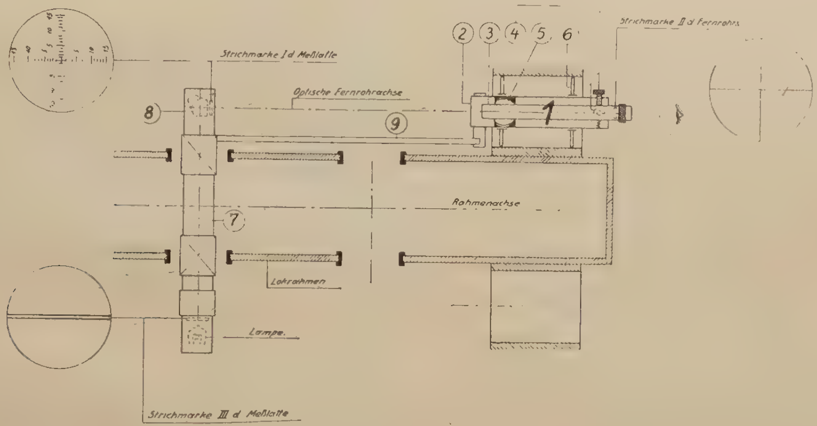
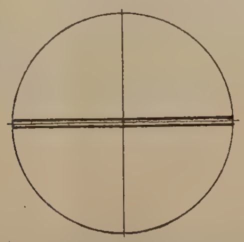



Fig. 1.

*Explanation of German terms :*

Lokrahmen = Locomotive frame. — Optische Fernrohrachse = Optical axis of the telescope. — Rahmenachse = Centre line of the frame. — Strichmarke d. Messlatte = Index of the gauge.

The gauge 7 consists of a steel tube in which the circular indexes I and III are inserted. The optical axis of the telescope is deflected exactly at right angles by means of the pentagonal prism 8 placed immediately behind the index I.



*Gauge at right angles to the optical axis of the telescope.*

Fig. 1*a*.

The gauge is suspended from the frame by means of special attachments which permit of its adjustment in all directions. The standard distances between the centre line of the cylinders and the centre line of the driving axle and from that of the driving axle to the coupled axles are set by means of the end gauges 9. The distances between the centre line of the axle and the faces of the horn cheeks are measured from the gauge 7 with special measuring instruments.

The gauge 7 is set in the following manner :

The internal tube 3 of the telescope is turned by means of the micrometer screws 4 until the optical axis of the telescope becomes exactly parallel to the

centre line of the frame. The details of this operation are described later. The gauge 7 is then turned by means of its

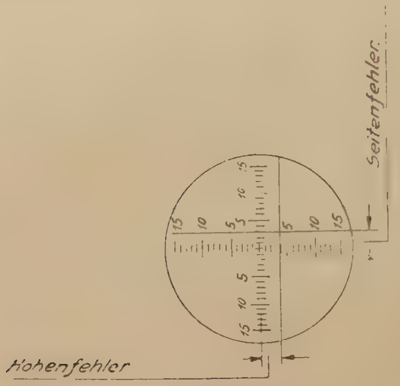



Fig. 1b.

*Note :* Höhenfehler = Vertical error. — Seitenfehler = Side error.

adjusting devices until the horizontal index II of the telescope coincides with the index III of the gauge (fig. 1a). The gauge is now exactly at right angles to the centre line of the cylinders and the frame. If the screws 4 are now adjusted to the zero mark, the obliquity of the cylinders in the vertical and transverse planes in millimetres (fig. 1b) can be read directly on the index I of the gauge 7. Figures 2 and 3 show the general layout of the telescope and the gauge 7.

In the German State Railways' repair

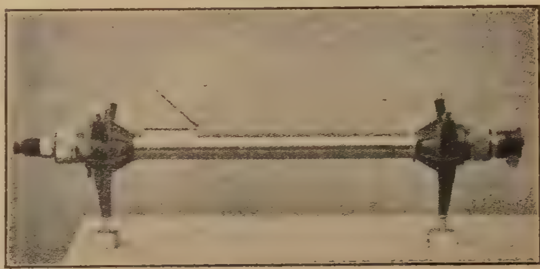


Fig. 2.

shop at Oels another optical and mechanical method is on trial which, compared with the above mentioned system, is still simplified and is likely to effect greater savings (1).

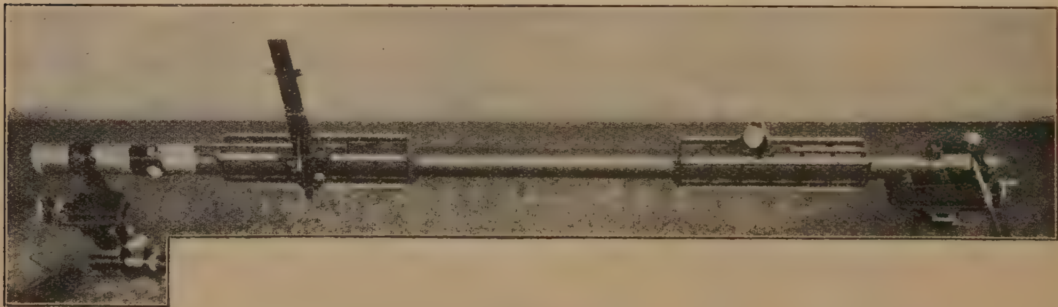


Fig. 3.

The essentiel feature of this method is that the centre lines of the axles are determined by adjustable screws fastened to the frames in a simple manner. The gauge has, therefore, only to be placed in the gap for the driving axle, and not in the others.

As optical instruments the telescope and the gauge are used, the latter however in a considerably simplified

(1) At the present time, the method has been perfected and since the end of March 1931 has been used with complete success.

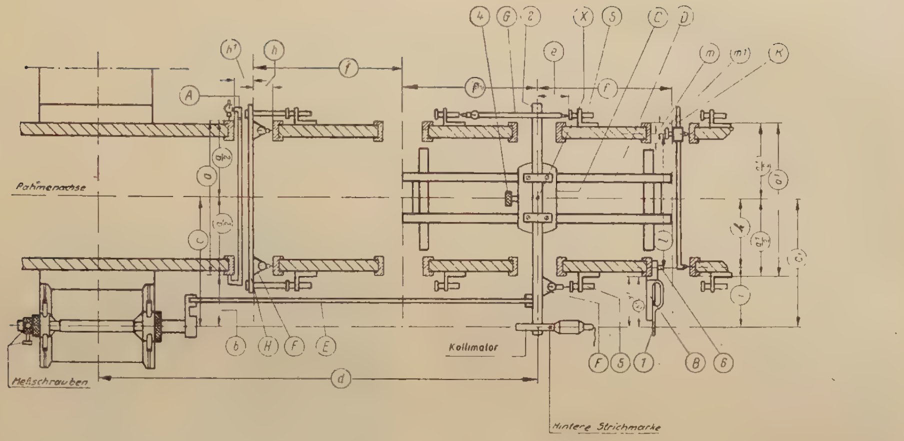



Fig. 4.

*Note* : Messschrauben = Micrometer screws. — Hintere Strichmarke = Back locating mark.

form. This new form consists of a steel tube, on one side of which a collimator is fixed perpendicularly to the tube. All the other measurements are effected by means of simple mechanical instruments which, in order to avoid errors of touch and in reading are fitted with counters wherever needed. The frame is measured up in the way shortly described below (cf. fig. 4):

1. The telescope is set up and the micrometer screws set to zero. The axis of the telescope then follows the direction of the actual centre line of the cylinder. The relative position of the centre line of the cylinder to the centre line of the frame is then determined. This is done by measuring with the instrument A the dimensions $a$ and $a_1$ on the side faces of the wedges (as not subject to wear) of the leading and trailing axles, or on the frame bar. The spacing straightedge B is then clamped to the wedge guide of the first and last pairs of wheels, and the dimensions $b$ and $b_1$ are read by means of the telescope on scale 1 of the spacing straightedge B. The difference between the dimensions $c$ and $c_1$ is calculated,

Example :

$$\frac{a}{2} = 623.55 \qquad \frac{a_1}{2} = 624.95$$

$$b = 473.00 \qquad b_1 = 466.00$$

$$c = 1096.55 \qquad c_1 = 1090.95$$

Thus the difference between $c$ and $c_1 = 1096.55 - 1090.95 = 5.6$. Therefore

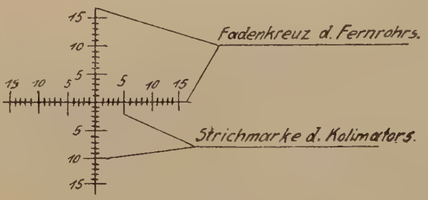



Fig. 4*a*.

*Note.* — Fadenkreuz d. Fernrohrs = Cross-hairs of the telescope. — Strichmarke d. Kolimators = Collimator locating mark.

the obliquity of the centre line of the cylinder equals 0.93 mm. per metre. The distance from one point measured to the other is 6 m. in this case.

2. The centre line of the telescope is then altered, by turning the micrometer screws, until the dimensions $c$ and $c_1$

are equal. This is effected if the dimension $y$ can be read on the scale of the spacing straightedge B. The dimension $y$ is not exactly equal to the dimension $b_1$ plus or minus the previously mentioned difference, because the centre of rotation of the telescope does not coincide with the point measured at the front end. For the sake of simplification the distance $y$ is therefore taken from a special table.

3. The slide C is fastened to the guiding rails D so that the gauge 2 is placed approximately half way between the wide faces of the driving horn checks. The slide C is then clamped on the rails D. The gauge 2 is fixed vertically to the centre line of the telescope and is swivelled round the point $x$ until, when looking through the telescope, the position of the index as shown in figure 4*a* becomes visible. The gauge is then truly at right angles to the optical axis of the telescope as well as to the centre line of the frame. The straightedge E is then put in place, and the gauge 2 is set by means of the adjusting screw 4 to the dimension of the drawings $d$ in the longitudinal direction.

4. The adjusting screws 5 on both sides of the driving axle gap are set by means of the measuring device F to a constant dimension $e$. Using the fixed dimension G the adjusting screws 5 of all the coupled wheel gaps are set. The length of the fixed dimension G equals the drawing dimension $f$ minus the length of the adjusting screws 5.

5. The horn cheeks and wedges are pop marked to the drawing dimensions $k$. For this purpose, the spacing straightedge B is secured in place. The scale 1, together with centre 6 is then displaced until, looking through the telescope, the dimension $i$ ($i = c_1$ — dimension shown on the drawings $k$) is read on scale 1. Pop marks are made on the horn cheeks and wedges with the centre punch 6. With the fixed trammel K, the drawing dimension 1 is transferred to the opposite faces, which are then pop marked also.

6. The dimensions $h$ and $h_1$ have to be determined in all the frame gaps by means of the measuring instruments F and H.

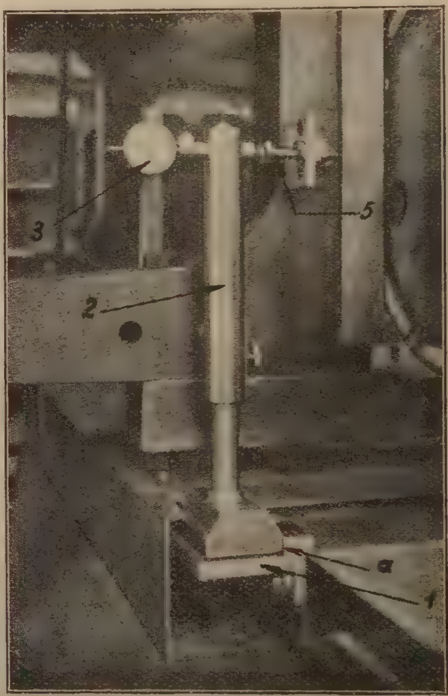


Fig. 5.

7. The dimensions $m$ and $m_1$ are checked over by means of a vernier calliper. In the event of the admissible wear exceeding 4 mm. (0.157 inch) the horn cheeks have either to be renewed or metal has to be welded on to the face.

*Figure 5.* The horn cheek faces are now ground and if this operation is done with a grinding machine the adjusting screws 5 (cf. also fig. 4) can be used to adjust the machine. The graduated faces $a$ of the try squares 1 on the

two sides are parallel to the bed of the grinding machine. The machine works at right angles to the centre line of the frame if the measuring instrument 2 is applied to the graduated faces on the left and right hand sides of the frames and if the pointers of the counter 3 show the same difference on both sides. Should the grinding be done by hand, the measuring instruments H and F (fig. 4) are used in order to check that the faces of the horn cheeks are truly parallel to the centre line of the axle.

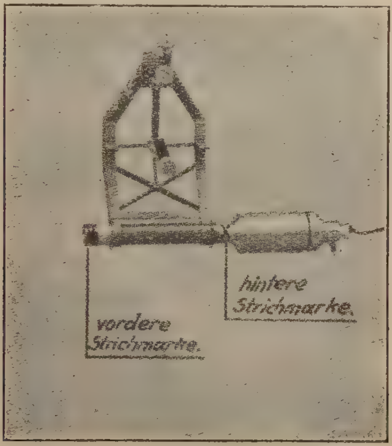



Fig. 6.

*Note :* Vordere (hintere) Strichmarke = Front (back) locating mark.

The vertical position of the horn cheek faces is then checked over by means of a spirit level.

*Figure 6.* It is also possible to check by means of the telescope, using the additional fitting shown in figure 6, the relative position of the slide bars to the centre line of the cylinders and to correct any mistake in a simple manner. For this purpose, a frame is clipped to the slide bars and carries at its lower end the collimator used in conjunction with the gauge (fig. 4). This collimator is fitted in such a way that its centre line is parallel to the contact surfaces of the frame. Consequently, if this frame is fastened to the slide bar, the axis of the collimator follows the line of the slide bars. If one looks through the telescope into the collimator attached to the slide bar, any change of direction can be read off directly. The sighting point is the back graduated index of the collimator.

In order to obtain the distance between the working faces of the slide bars and the centre line of the cylinders, the index at the front end of the collimator is used as the sighting point of the telescope. The telescope is adjusted with very great accuracy according to the millimetric divisions of this graduated index. The side and vertical distances of the working faces of the slide bars to the centre line of the cylinder can be directly read off within an accuracy of about 0.5 mm. (0.0197 inch). (Even tenths of a millimetre can, if necessary, be estimated with accuracy.)

For setting frames by *a*) the mechanical method and *b*) the optical method described above and used in the Tempelhof repair shops timings made have shown that 21 hours is taken with the method using straightedges and try squares and 12 3/4 hours with the optical method for a 6-wheeled engine frame, representing a saving of 40.7 % in favour of the optical system. Using the method perfected by the Oels repair shops on a 10-wheeled locomotive frame, these periods were 25 hours for method *a*) against 6 hours for method *b*), so that a saving of 76 % has been effected.

The upkeep of the straightedges and try squares, etc., involves considerable expenditure for the reasons stated previously. Owing to the simple construction of the optical instruments their cost of upkeep is likely to be lower. In as much as the initial outlay is also *less* than that of the mechanical measuring system, the optical method of setting locomotive frames can be considered a noteworthy progress made in this field.

[ 625 .172 (.944) ]

# New method of automatically locating vertical defects in permanent way,

by C. A. CARDEW, M. I. Loco. E.,
New South Wales Government Railways.

*(The Railway Engineer.)*

In order that locomotives and rolling stock may operate safely and smoothly over permanent way at high speeds it is an accepted fact that what is known as « a good running top » is essential. The maintaining of an even top under modern conditions of high speeds and heavy axle loads calls for rigid inspection of the road and a high standard of maintenance by the track gangs. Despite such vigilance, however, it is well known that « working joints » and « drummy » sleepers exist in the finest tracks, and even though no unevenness in the surface of the rails is apparent to the eye, such defects can, and do, occur under the imposition of heavy weights. That any excessive unevenness, or departure from true alignment in a vertical direction, is a very common cause of derailments is certain, and in this connection some extracts from a paper on derailment read before the South American Centre of the Institution of Locomotive Engineers by Mr. Sedgfield, at that time Chief Mechanical Engineer of the Central Uruguay Railway, are pertinent.

Amongst his remarks the following statements will be found : « The outstanding characteristic of most, if not all, derailments in the mounting of the wheel flange, which after running some 3 or 4 metres diagonally across the rail surface, and leaving a mark of its track easily traceable, drops on the outside.... This kind of derailment is due to one immediate cause, and one only, viz., a temporary disturbance of load distribution over the wheels of the vehicle, resulting in the wheel which mounts the rail being relieved to a great extent of the load it should normally carry.... Track irregularities may be defined as defects of alignment of rail surface in both horizontal and vertical planes, but the latter are those chiefly responsible for disturbance of load distribution. They originate as a result of uneven support of the sleepers and dropped rail joints, and when associated with high centres of gravity and speed may set up oscillations and lurchings which inevitably have a most marked effect in disturbing load distribution. »

From the foregoing it will be understood that the existence of depressions of any considerable magnitude in railway track are liable to produce a swaying and lurching of the vehicles passing over them, which, having a centre of gravity as high as 6 to 7 feet above rail level, will suffer serious interference with the weight carried by their various wheels in consequence.

Apart from the effect of these swaying and lurching movements, which occur more particularly at high speeds, any unevenness of rail surface will, even at low speeds, affect the weight distribution directly through the spring system of the vehicle. This is particularly so if no compensating levers are employed, and on four-wheeled stock, and as a result

of the movements produced, the springs themselves are liable to suffer damage. The effect and extent of the action which takes place will be appreciated when it is realised that many springs are in use under locomotives whose deflection from an unloaded condition to their position under designed load is less than 1 1/2 inches, whilst with some unladen goods vehicles it is even less than 3/4 inch. When a vehicle is called upon to traverse permanent way which has local depressions within the length of its wheelbase, of 3/4 inch, or even more (a condition which, it can be stated from experience on several railways, is much more common than is generally supposed), the variations occurring in the loading of the springs, with consequent risk of derailment, and the effect on the springs themselves, and on the vehicle generally, will be apparent.

*Causes of track irregularities.*

The main causes which result in a bad running top in existing track may be enumerated as follows, viz. :

*a*) Soft or spongy road bed, due in most instances to bad drainage.

*b*) Insufficient or unsuitable ballast.

*c*) Ballast not properly packed under sleepers, especially at joints, which are the weakest part of the track.

*d*) To a lesser extent than the foregoing, and, in the case of old sleepers, the rails, or chairs, may be cutting into the sleepers themselves.

The conditions mentioned above will, according to the nature of the defect, and if allowed to remain, result in « pumping » and « drummy » sleepers, « working joints », and ultimately, in all cases, a permanent deformation in the rails themselves, especially in the neighbourhood of the joints.

*Existing methods of track inspection and maintenance.*

The elimination of all these troubles is almost entirely a matter of inspection and maintenance. The usual inspection method by patrolling the track either on foot or by trolley is probably quite satisfactory as a means of observing horizontal alignment and the conditions of sleepers and fasteners. It will be realised, however, that in very many cases such an inspection must fail to detect many weaknesses due to the condition of the roadbed under the sleepers, as the presence of these will not be suspected, and can be revealed only if, by chance, a train traverses the place whilst the inspection gang is on the spot. The shortcomings of the usual method of inspection are recognised by the permanent way authorities of many railways, and it is quite a common practice to detail an inspector to ride on the engines and note the location of any rough riding that may be experienced.

This is an excellent practice, but is has its limitations, in that the natural period in the rolling and pitching motion of the engine will often serve to accentuate a comparatively minor track defect, and conversely, to cloak completely, or mitigate considerably, a comparatively large one, thus giving a false impression to the observer. Also, different engines, or even the same engine after side play has developed, will ride differently, so that with a bad riding engine even a good track will appear indifferent, or with a good engine a bad track may seem passable. In addition there is always the difficulty for the observer of accurately recording the location of any severe impacts or lurches, especially if occurring at frequent intervals, or if, as is often the case, the observations have to be made at night.

Because of the difficulties and short-

comings of the usual methods, progressive railway administrations are making increasing use of special cars (usually dynamometer cars), equipped with apparatus designed for recording various defects in the permanent way, including vertical irregularities, which, as previously pointed out, are the more serious and most difficult to detect.

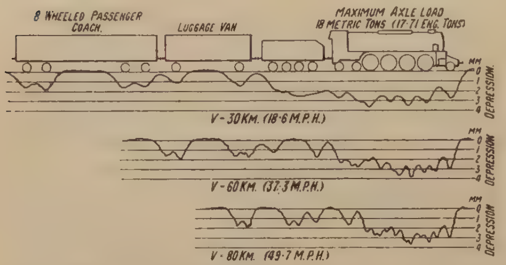



Fig. 1. — Depression of rail under live load, Wirth system.

The use of these cars is to be commended, but they are expensive to construct, and, being non-paying dead weight in a train, costly to haul, and in many cases their presence may require the use of an assisting engine. Furthermore, whilst these cars are heavy when compared with ordinary carriage designs, their axle loads will not usually approach those of a modern heavy locomotive. In fact the static weight imposed upon the rails by any one of the driving axles of the heaviest locomotive employed by the average railway will by fifty to one hundred per cent greater than that of the car axle, and will be further augmented by the dynamic forces due to the counterweights. In this connection the accompanying diagram (fig. 1), taken from the issue of *The Railway Engineer* for February 1932, is interesting, as it shows the actual depression recorded on the special form of spring supported track designed by the late Dr. Wirth, of the Austrian Federal Railways, under locomotive and train at various speeds.

It would hardly seem satisfactory, then, when a track has been designed to carry the axle and impact loadings of the locomotive, to test it by applying the axle loadings of a car, which, it has been shown, is so much less than that due to the locomotive.

*A new method of track inspection.*

With a view to evolving a method whereby excessive vertical irregularities in railway track may be detected under maximum load and accurately located in a scientific manner, instead of by the usual visual inspection, and at the same time without the expense involved in building and running a special car, and with the further advantage of employing the weight of the locomotive for the purpose, the writer has perfected a device which has become known as a track depression indicator on the railways where is has been employed.

This instrument, the main features of which have been patented, functions electrically, and it can be used on any locomotive whilst the latter is engaged on its regular train duties. It serves to detect, record, and mark on the track any unevenness which may exist in the surface of the rails, or which may be produced by the weight of the locomotive as it passes over them, and which is in excess of the amount for which the machine is set. In figure 2 the device, with its associated equipment, is shown attached to a locomotive and ready for service.

It consists primarily of detectors ($a$) one on each side of the engine, mechanically connected to the axle boxes, and moving in response to wheel movements due to irregularities in the track, and it can be set at will to operate only when those irregularities exceed any predetermined amount. The detectors are also capable of employing a minor and major setting at one and the same time, so that a distinction is made be-


Fig. 2. — Cardew track depression indicator fitted to locomotive.

tween depressions of a lesser and those of a more dangerous nature. The detectors control, by electric circuits, relays, housed in a relay box (*b*), whose function is to show by means of light signals when a track defect has been encountered, the minor or major extent of the fault being indicated by the operation of the appropriate light. The relays also control the movements of pencils which record on a moving paper ribbon the location and extent of the depression, and a counter which keeps tally of the number registered throughout the test. Finally, the relays control the operation of a valve, the discharge jet of which can be seen at (*c*), and which ejects a charge of liquid kalsomine on to the rail at the defective place from the tank (*d*), containing the mixture under pressure. Situated above the pressure tank is a convenient form of charging vessel (*e*) by means of which the tank can be quickly recharged with marking mixture whilst the engine is travelling. A small 12-volt storage battery which supplies the current required for the whole system is housed in a small cupboard behind the pressure tank, and marked (*f*).

*Details of equipment detectors.*

The track depression indicator depends for its actions upon the functions performed by the detectors, photographs of which are reproduced in figure 3 (front view with cover removed) and figure 4 (back view).

The main features of the detector are a disc (*a*, fig. 3) mounted on a spindle (*b*), and having insulated contacts (1, 2, 3, 4) of different lengths, and a framework carrying brushes (I, II, III, IV), which bear upon the disc contacts, the framework in turn being mounted upon a hollow spindle surrounding spindle (*b*). This hollow spindle is attached to arm (A, fig. 4), whilst spindle (*b*) is attached to arm (B), these

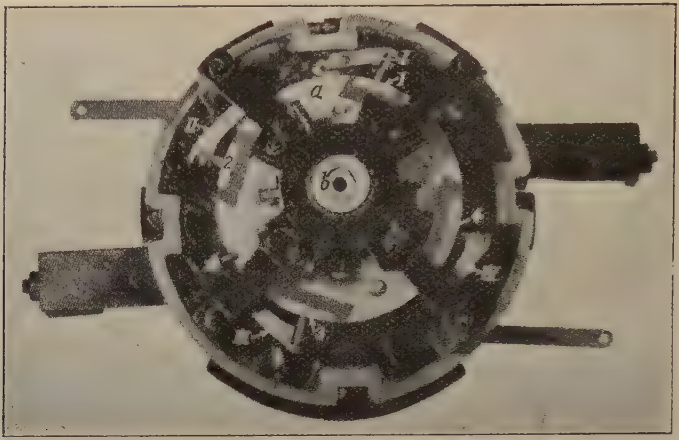


Fig. 3. — Front view of detector, with cover removed.

arms being located behind the detector, and their movement being restrained by springs C and D.

The complete detector is mounted on the locomotive, in any convenient position, either on the frame, running board, bracket, or other fixed and rigid structure. One of the arms is then coupled by means of a flexible steel wire passing round pulley wheels to, say, the leading coupled axle box, and the other to, say, the trailing box, the wires being kept taut by the springs on the arms before mentioned.

Any of the coupled boxes are generally suitable, but it is usually most advantageous to employ two as remotely disposed from one another as possible. The detector must now be set to its zero position, which can be done by placing

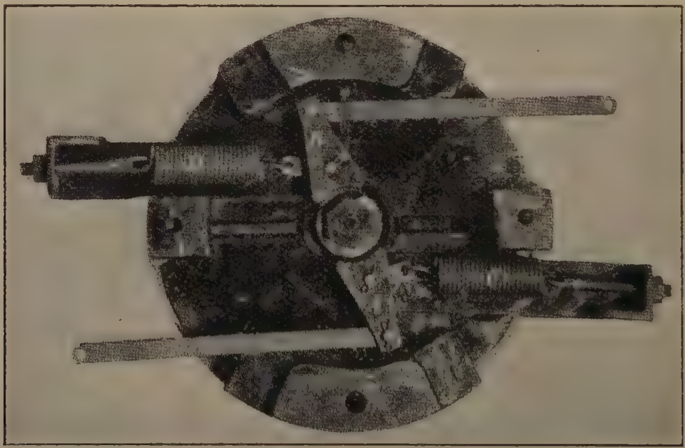


Fig. 4. — Back view of detector.

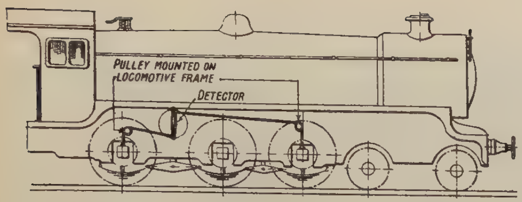



Fig. 5.

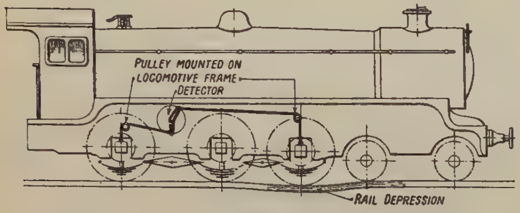



Fig. 6.

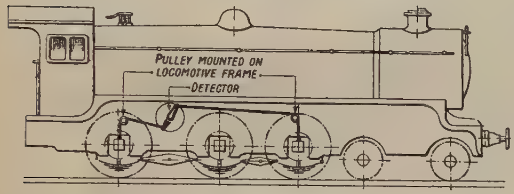



Fig. 7.

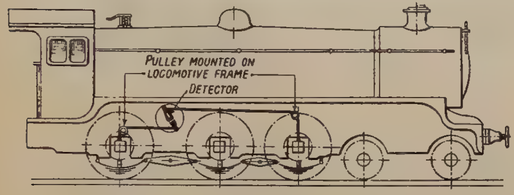



Fig. 8.

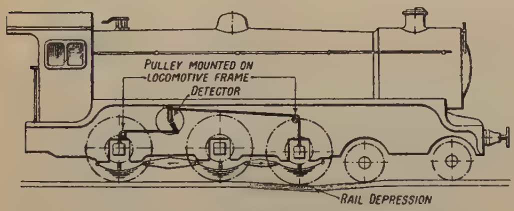



Fig. 9.

Diagrams showing the working of the detector.

the locomotive on a perfectly even, rigid track (a good turntable is convenient), and adjusting by means of the screws (not shown in the figures), and scale provided on the disc. When set in this fashion each brush (I, II, III, IV, fig. 3) will be central on its contact (1, 2, 3, 4), and the arms (A, B, fig. 4) will be in line with one another, and perpendicular. The action of the detector can now be followed by reference to the diagrams, figs. 5, 6, 7, 8 and 9.

In figure 5 the detector is set to zero, and the engine is on a perfectly even track, and subject to no rolling or oscillation. Figure 6 shows the engine again without oscillation, but with the leading wheel entering a depression in the track. The movement of one arm relative to the other should be noted. In figure 7 the engine is shown again on an even track, but with the frame and upper portion lurching or rolling away from the observer. No relative movement in the disposition of the arms occurs under these conditions. Figure 8 shows the state of affairs with the engine rolling in the opposite sense, the arms changing the direction of their movements but again remaining without change of angle between one another. Figure 9 shows the engine again with a rolling motion, but at the same time with the leading wheel entering a track depression, and it will be observed that, besides moving together due to the roll, the arms move relatively to one another.

In the manner described the mechanism eliminates the false results which would otherwise be produced by rolling of the superstructure, whilst still permitting it to detect uneven track. There remains the possibility of errors due to longitudinal pitching, but it is found these are not serious, and furthermore, pitching itself is usually due to a series of vertical irregularities in the track.

It will be understood from the previous description of the detectors that so long as the arms do not more relatively one to another, the disc and brushes do not do so either, but remain centrally disposed. The circuits are so arranged that, whilst the brushes are on the

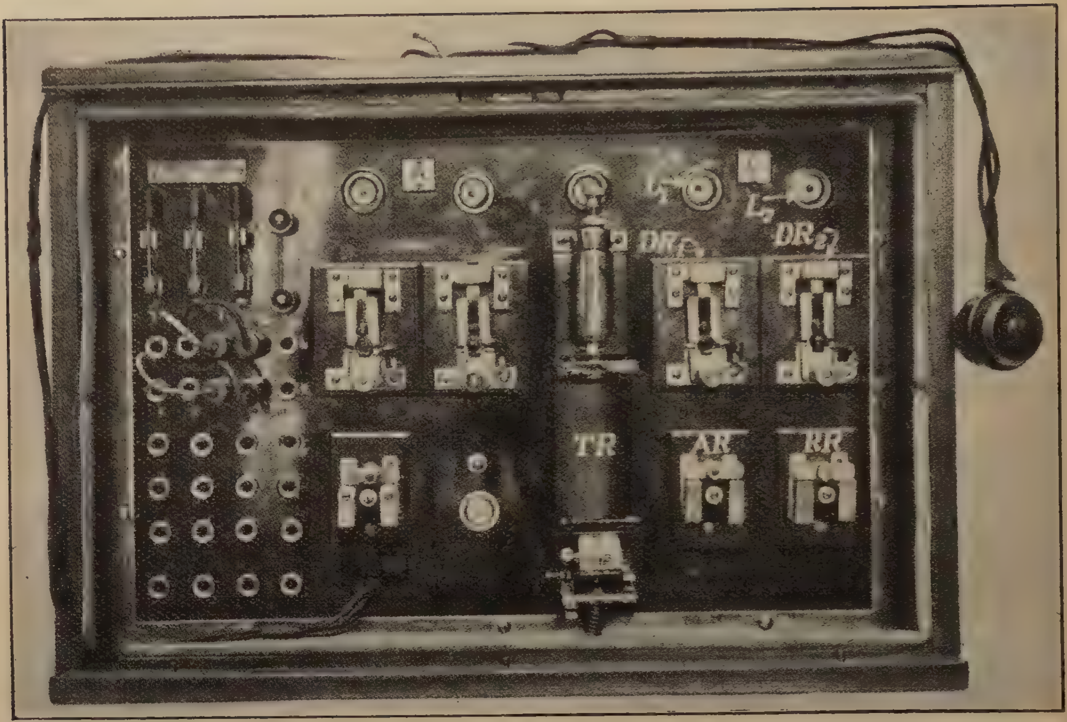



Fig. 10. — Relay box.

contacts, current is flowing, and all the relays in the relay box are held inoperative. As soon as relative movement takes place sufficiently to displace a brush from its contact, the relay concerned functions. It will also be realised that the four different contact lengths shown provide for recording irregularities of various magnitudes, and, as already pointed out, any two may be selected for use at the same time, one serving to detect lesser and the other major depressions.

*Relay box and recording ribbon.*

The purpose of the relay box is simply to record those detector movements which are in excess of the selected amount, in the form of light signals in the cab, location marks on the recording ribbon, and whitewash marks on the track.

It will be unnecessary to describe the construction of the relay box (fig. 10), but the sequence of events when an indication of a track irregularity is received from the detectors will be detailed. Normally, current is flowing from the battery to the wiring system on the engine, through the brush and contact segment of the detector, and back to the armature of one of the relays, say $DR_1$ in figure 10, through the relay, and thence to the battery.

When this circuit is interrupted by the movement of the detector brush off its contact, the relay $DR_1$ is de-energised, its armature is released, and in its new

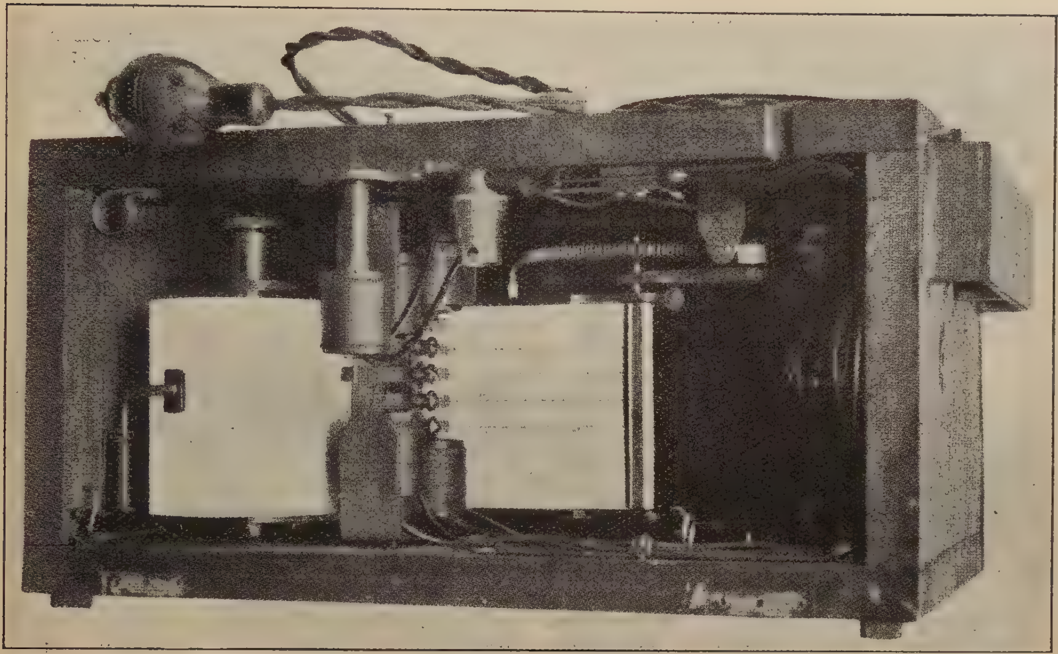


Fig. 11. — Housing of recording ribbon.

position switches current on to a light $L_1$ and to another relay AR. The movement of this second relay energises the time relay TR (whose speed of travel can be varied by means of an adjustable dash-pot device), and also operates the magnet of one of the pencils of the recording ribbon.

Whilst the time relay is in motion current is flowing to the electrically-operated paint spray valve, and, upon completion of its stroke, the time relay de-energises this valve and turns current on to a final relay RR whose action re-establishes a circuit through the detector (provided the brush has returned to its contact) and re-energises relay $DR_1$. The movement of the latter's armature at once re-establishes the original normal flow of current as outlined in the first place, and all the other relays are de-energised, and ready for recording another depression. The introduction of the time relay ensures that when traversing a fault in the track at high speed a sufficient interval is allowed for the illumination of the lights and the lifting of the paint spray valve.

It is for similar reasons of speed that the whole system employs a normally closed circuit, for the breaking of this ensures quicker response of relay $DR_1$ than would the making of it, with the consequent risk of failing to respond to the detector at high speed. The events for the adjoining relay $DR_2$ which is connected to the same detector, but to the larger segment, are similar, except that its armature, when released, besides lighting its light, $L_2$, direct, also operates the appropriate pencil on the ribbon direct, and the relays AR and RR are not employed in the circuits. The re-setting is done instead by a push button, the idea being that the operator may specially note the occurrence of

these excessive, or dangerous, irregularities. As the relay AR is not operated by $DR_2$ it follows that the time relay TR is not either, but as $DR_1$ is connected to the smaller segment, if a larger irregularity brings $DR_2$ into action, $DR_1$ must operate immediately prior to it, so that through its medium the time relay discharges the necessary functions of operating the paint spray, etc.

The recording ribbon is separately housed, the assembly being shown in figure 11. It consists of serrated rollers, driving a paper ribbon, upon which bear ordinary lead pencils. The rollers are driven by an arm with a ratchet engaging a toothed wheel, the wheel being mounted on one of the rollers. The arm is driven to and fro (ratchet engaging and disengaging one tooth at a time) by an electro-magnet, which is energised and de-energised by a small rotating make-and-break device driven direct from the end of one of the tender axles.

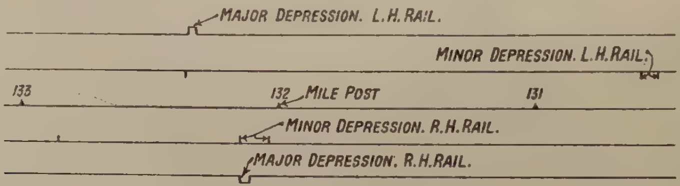



Fig. 12. — Specimen record.

It therefore follows that the travel of the ribbon is proportionate to a reduced scale (about 3 inches a mile), to that of the engine. The pencils, of which there are five, draw a straight line until operated by one of the relays from the relay box, as already described, when they deflect laterally. Two pencils on one side correspond to the minor and major irregularities on one rail, and two on the other to those on the other rail. The centre pencil is hand operated by an electric push button, and serves to mark the location of mile posts, stations, or any other desired point. A specimen record as made on the ribbon is shown in figure 12.

### *Whitewash tank fillers and discharge valve.*

The remainder of the equipment is very simple and requires little description. In figure 13 two fillers or charging hoppers (*a, a*) are shown on the tender, mounted above, and connected to the whitewash tank (*b*). The latter, which is an old Westinghouse brake reservoir, contains the liquid under pressure, from any convenient source, in the case shown, from the air brake. A pipe from this tank leads down to the discharge valve (*c*), which is a plain electrically-operated type of valve, and discharges against the inside edge of the rail.

The location and details of all this part of the equipment can be varied to suit local conditions, but it is advisable to place the valve at the leading end of the tender as shown, for by doing this experience proves that the mark made on the rail more nearly coincides with the actual fault than if the valve be placed anywhere else. Even so, of course, as the speed of the locomotive varies there is a discrepancy, but under the most extreme circumstances this does not amount to more than a few feet either way. For the sake of simplicity, only one valve is employed, marking the left-hand rail, so that it is necessary to make it plain to the permanent way staff that such marks indicate the presence of an irregularity in either the marked rail, or that opposite the mark, or in both.

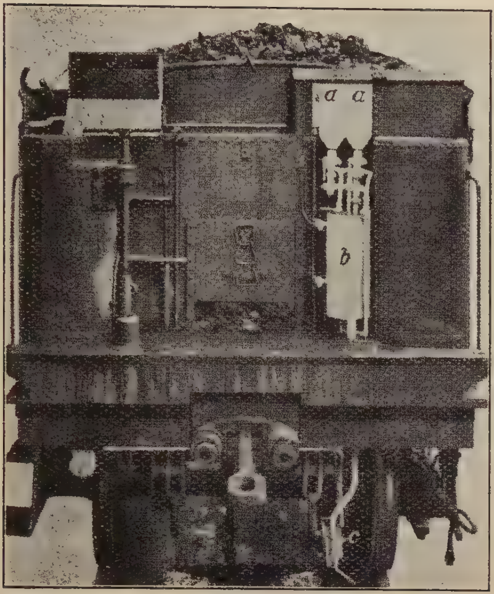


Fig. 13. — Whitewash apparatus mounted on tender.

*Results obtained in service.*

Many tests have been made on several Australian railways with the track depression indicator by various independent authorities, and all have conclusively proved that the machine is reliable and accurate within very close limits. The usual road test is to inspect a place on the open track which has been marked after the passage of the engine equipped with the device. A fine line about equal in length to the engine wheel base is then stretched across the spot and any initial irregularity (either depression or hogging) is measured. In the case of a depression, a spike is then driven into the ballast at the spot and its head pushed over until the bottom of the rail just rests upon it, and after the passage of the same, or another engine of the same type, the distance between the spike head and rail is measured. The total depression under load is then approximately the sum of the initial irregularity plus the deflection shown by the movement of the spike. In the case of a hogged rail the same procedure is adopted, but the spike is inserted at the beginning or end of the hog. The measurements taken thus have been checked with the wheel movement which it has previously been found is necessary to operate the contact in use, and the two measurements have been found to agree closely. This procedure is illustrated by figure 14.

Since the machine has been in service on various railways it has proved a valuable check upon the permanent way conditions, revealing many unsuspected weaknesses, the rectification of which, before further development, has undoubtedly removed derailment hazards. The failure to take prompt action to rectify defects marked has, in several instances, resulted in derailments at these places. The machine has proved

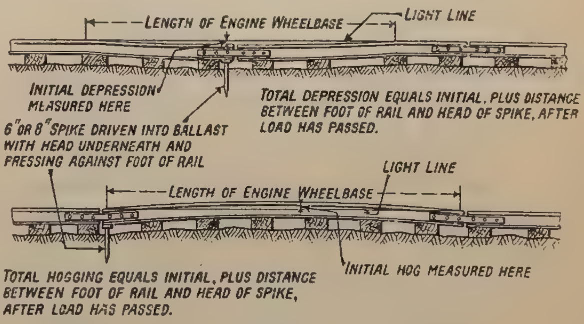



Fig. 14.

a particularly valuable adjunct in checking the track in tunnels where inspection is difficult, and has also been of service in recording deflections in timber bridges from time to time.

With regard to the results obtained by running the device over the lines on a regular schedule, the graphs shown in figure 15, supplied by courtesy of the Victorian Railways, are interesting,

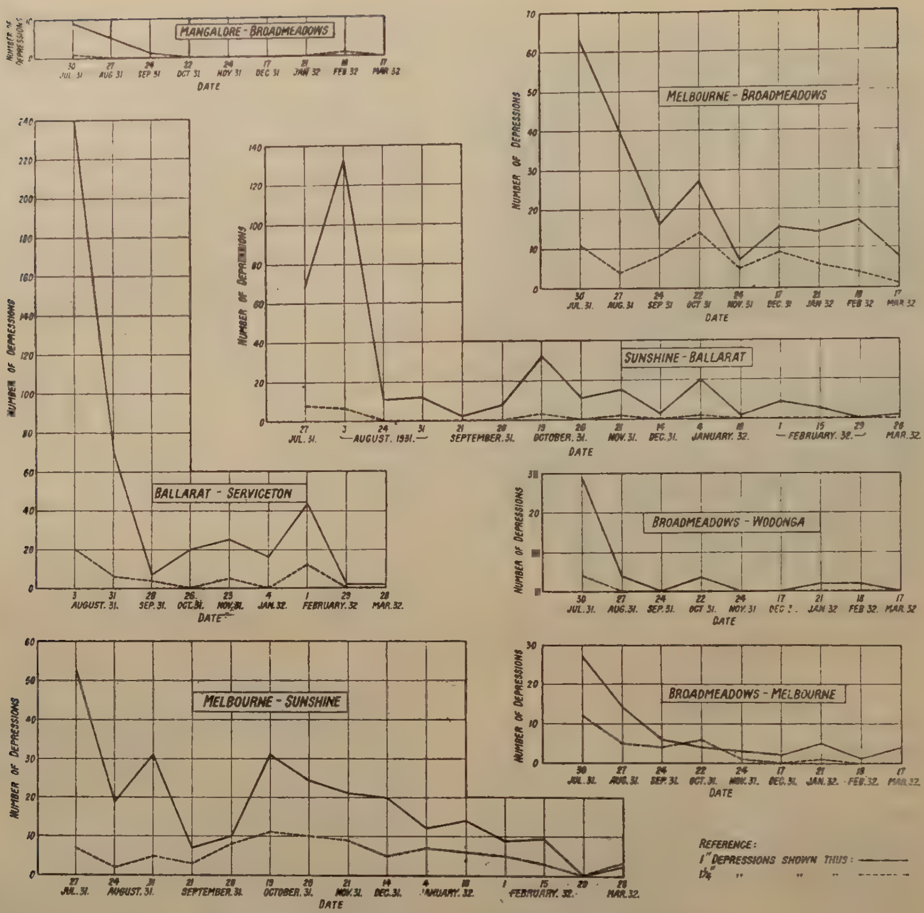



Fig. 15. — Depressions registered by track testing.

showing a progressive improvement in the track with each successive trip.

It is contended, and the graphs shown go far to prove, that it is possible to improve the running top of the permanent way by the use of this indicator without any increase in maintenance costs other than the cost of equipping an engine and running the apparatus. That such an improvement is desirable cannot be disputed, involving, as it does, smoother and more comfortable riding, less damage to springs and wear and tear to rolling stock, and the elimination of many track weaknesses which are, admittedly, a frequent source of derailments, and consequently a menace to public safety.

[ 621. 131.2 & 621. 133.5 ]

# Relation of back pressure to locomotive performance,

By George W. ARMSTRONG.

*(Railway Mechanical Engineer.)*

Low back pressure has become a subject of general discussion in recent years and a general opening up of exhaust nozzles has been the result. In many instances low back pressure has been attained, but since no compensating change has been made in the type of exhaust nozzle to improve draft efficiency, there has been a reduction in draft which frequently has resulted in what is known as a hard-steaming locomotive.

Low back pressure in itself is well worth seeking. The back pressure on the piston acts as a brake, decreasing the work output of the locomotive and, therefore, the drawbar pull and the consequent speed-hauling ability of the locomotive. However, unless an engine is over-drafted, any opening up of the exhaust nozzle to reduce the back pressure will adversely affect combustion and, if the steaming ability of the engine is affected enough thereby, there may be no improvement in engine performance, even though low back pressure is attained.

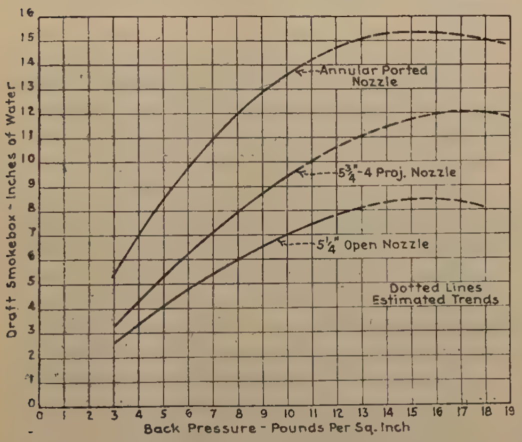



Fig. 1. — The relation between draft and back pressure for different types of nozzles and the limitations in draft production.

Authentic information as to the effect produced by reducing back pressure is unfortunately meager. The locomotive test plant affords the only means for evaluating effects and all published tests have been directed toward study of a respective design of locomotive or a major locomotive appliance and, with one possible exception, develop no information which throws light on the subject of back pressure.

*Pennsylvania Bulletin* No. 32, covering the test of the Pennsylvania class I-1-s locomotive, a 2-10-0 type with 50 % restricted cut-off, with and without the open-type feedwater heater with which it was equipped, reveals some of the effects of reduced back pressure. Data selected from these tests are given in table I. The primary interest of these data lies, first, in the establishment of the fact that reduced back pressure does result in increased drawbar pull and, second, in the apparent fact that a considerable portion of this increased drawbar pull results from a reduction in the locomotive internal resistance or friction drawbar pull, which results from reduced brake action of the back pressure rather than from any appreciable increase in cylinder output or indicated horsepower.

As seen from table I, there is in general an increased indicated horsepower at the higher exhaust pressures while there is a very marked reduction in friction drawbar pull at the lower ex-

haust pressures. With the locomotive operating at 40 % cut-off, at a speed of 21.9 m.p.h., the comparison is :

| Test. | Exhaust pressure, lb. | Drawbar pull, lb. | Tractive force, lb. | Friction drawbar pull, lb |
|---|---|---|---|---|
| 5946* . . . | 9 | 38 348 | 51 849 | 13 127 |
| 5914 . . . | 7 | 39 328 | 50 815 | 11 462 |
| 5916 . . . | 7 | 40 160 | 51 846 | 11 660 |

* Test with injector.

The difference in friction drawbar pull between test 5946 and the average of tests 5914 and 5916 is 1 566 lb. The horsepower difference at this speed of 21.9 m.p.h. for 2 lb. difference in exhaust pressure is as follows, assuming that as the mean effective pressure :

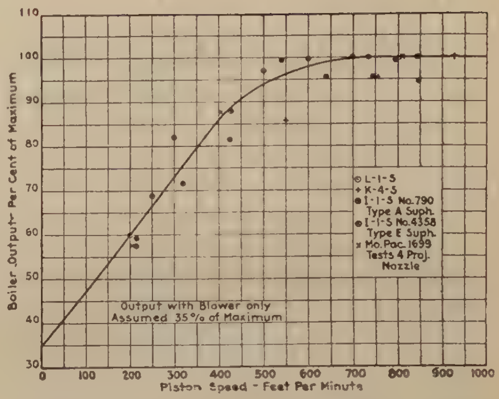



Fig. 2. — The relative percentage of boiler output with respect to the maximum at various piston speeds.

$$\text{H.P.} = \frac{\text{M.E.P.} \times \text{piston area} \times \text{piston speed}}{33\ 000} = \frac{2 \times 2 \times 572.56 \times 640}{33\ 000} = 44.4$$

$$\text{H.P.} = \frac{\text{Speed} \times \text{tractive force}}{375}, \text{ so T. F.} = \frac{44.4 \times 375}{21.9} = 761 \text{ lb.}$$

We see that 761 lb. of the total 1 566 lb. frictional drawbar pull results from removing the braking action of the back pressure. Presumably there is some other unaccounted for action to account for the remaining 805 lb., such as a small increase in mean effective pressure and therefore indicated horsepower, which, however, is last in reducing the area of a small indicator card.

F. A. Goodfellow, supervisor of fuel and locomotive service, Pennsylvania, in discussing a paper by R. E. Woodruff, system operating vice-president, Erie, on « Our Experience in Saving Coal », before the September 1930, meeting of the New York Railroad Club, had this to say :

« On the effect of reducing back pressure due to increasing exhaust nozzle areas, the results referred to were taken from tests of a class I-1 locomotive having 30 1/2-inch by 32-inch cylinders, 250-lb. boiler pressure, a 50 % limited cut-off, grate area of 70 sq. feet, 62-inch diameter drivers and 6 255 sq. feet of heating surface.

« There were six tests made varying in speeds from 7.3 to 29.1 m.p.h. The nozzle referred to as standard was of the four internal projection type with an area of 33 sq. inches. The nozzle used for comparison was of the multiple point type with an area of 45 sq. inches or an increase of 36 %.

« The total dry coal fired per hour on both sets of tests varied from 2 100 lb. to 12 800 lb. The water evaporated was between 18 000 lb. and 67 000 lb. per hour. The indicated horsepower was 800 H. P. to 4 000 H. P., the dynamometer horsepower from 600 H.P. to 3 400 H.P. With drawbar pull ranging from 31 000 lb. to 34 500 lb. and burning coal up to 3 800 lb. of dry coal per hour, there was no increase between the two nozzles, although the decrease in back pressure ranged between 30 and 40 %.

« When the locomotive was worked at 14.6 miles per hour and full cut-off, the increase in drawbar pull was 5.4 % with a reduction in back pressure of 31 % in favor of the large nozzle. At 21.9 miles per hour and full stroke, the

TABLE I.

**Increase in drawbar pull effected by reduction in back pressure.**

| Test designation. | Exhaust pressure. | Temperature of exhaust. | Mean effective pressure. | Cut off. % | Steam chest pressure. | Initial pressure. | Pressure at cut off. | Least back pressure. | Indicated H. P., total. | Water per ind. H. P.-hour | Drawbar pull. | Tractive effort from ind. H. P. | Friction drawbar pull. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40-20-F | 2 | 221 | 86.6 | 21.7 | 247 | 224 | 168 | 1.4 | 797 | 20.7 | 29 600 | 41 958 | 12 337 |
| 40-20-F | 1 | 220 | 82.7 | 20.1 | 243 | 224 | 171 | 0.7 | 761 | 23.0 | 27 469 | 40 073 | 12 585 |
| 40-20-F | 1 | 220 | 84.3 | 20.3 | 243 | 226 | 169 | 0.6 | 776 | 20.8 | 32 578 | 40 847 | 8 248 |
| 40-30-F | 2 | 228 | 117.0 | 30.9 | 246 | 234 | 179 | 0.6 | 1 077 | 20.8 | 43 408 | 56 730 | 13 291 |
| 40-30-F | 2 | 226 | 118.3 | 31.5 | 245 | 234 | 179 | 1.3 | 1 089 | 19.4 | 46 842 | 57 335 | 10 464 |
| 40-40-F | 3 | 235 | 143.2 | 39.3 | 245 | 239 | 193 | 1.4 | 1 318 | 20.9 | 54 817 | 69 415 | 14 585 |
| 40-40-F | 2 | 232 | 142.6 | 39.8 | 243 | 236 | 190 | 0.1 | 1 314 | 19.6 | 58 837 | 69 172 | 10 300 |
| 80-20-F | 2 | 221 | 64.7 | 20.6 | 245 | 208 | 139 | 2.6 | 1 192 | 18.1 | 20 258 | 31 376 | 11 103 |
| 80-20-F | 2 | 220 | 65.5 | 20.6 | 243 | 203 | 137 | 1.5 | 1 228 | 17.6 | 25 315 | 32 324 | 6 992 |
| 80-30-F | 4 | 229 | 97.4 | 31.7 | 244 | 223 | 148 | 3.6 | 1 794 | 16.0 | 34 078 | 47 240 | 13 137 |
| 80-30-F | 3 | 230 | 91.8 | 29.9 | 243 | 223 | 149 | 2.9 | 1 689 | 18.2 | 32 792 | 44 480 | 11 667 |
| 80-30-F | 3 | 228 | 98.6 | 31.6 | 241 | 224 | 149 | 2.1 | 1 815 | 16.8 | 39 597 | 47 782 | 8 161 |
| 80-40-F | 6 | 241 | 121.4 | 40.7 | 241 | 232 | 157 | 3.9 | 2 235 | 16.4 | 45 812 | 58 854 | 13 010 |
| 80-40-F | 5 | 235 | 122.1 | 39.4 | 240 | 234 | 160 | 3.0 | 2 248 | 15.9 | 49 794 | 59 188 | 9 363 |
| 80-50-F | 10 | 286 | 147.4 | 50.1 | 241 | 237 | 176 | 6.3 | 2 715 | 16.8 | 57 994 | 71 495 | 13 463 |
| 80-50-F | 7 | 259 | 150.1 | 50.5 | 242 | 236 | 175 | 4.0 | 2 766 | 16.8 | 63 263 | 72 821 | 9 521 |
| 120-40-F | 9 | 256 | 106.2 | 40.1 | 242 | 218 | 148 | 10.0 | 2 933 | 14.9 | 38 348 | 51 849 | 13 127 |
| 120-40-F | 7 | 241 | 104.8 | 40.0 | 238 | 219 | 145 | 8.0 | 2 895 | 15.5 | 39 328 | 50 815 | 11 462 |
| 120-40-F | 7 | 243 | 106.9 | 41.1 | 242 | 222 | 142 | 7.0 | 2 954 | 15.8 | 40 160 | 51 846 | 11 660 |
| 120-40-F | 7 | 242 | 104.5 | 40.3 | 241 | 215 | 144 | 8.4 | 2 895 | 15.6 | 43 515 | 49 290 | 5 814 |

Test with injector—others with open-type feed water heater.

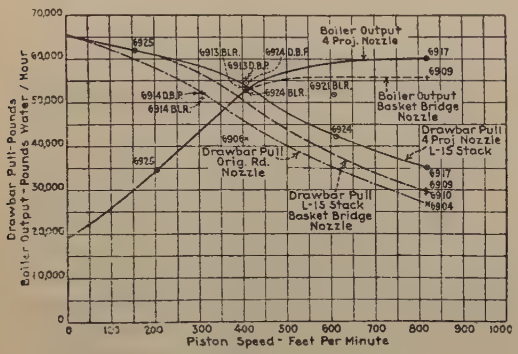



Fig. 3. — The effect of various types of nozzles on drawbar pull and boiler output as revealed by tests of a three-cylinder 2-8-2 type locomotive.

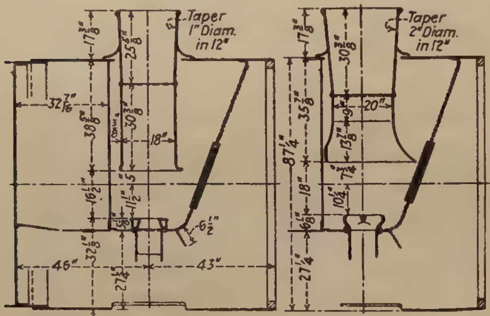
increase in drawbar pull was 6.4 % with 37 % decrease in back pressure in favor of the large nozzle. At the maximum rate for operating the locomotive, or 29.1 miles per hour and full stroke, with a dry coal per hour rate of 12 000 lb. and evaporating between 65 000 lb. and 67 000 lb. of water per hour, the increase in drawbar pull was 11.5 % with a reduction of 32 % in back pressure in favor of the large nozzle. These tests showed there was practically no difference in the dry coal or dry steam per indicated or dynamometer horsepower with the two different nozzles. »

The tests run in 1899 by Don Sweney through joint co-operation of the University of Illinois and the Illinois Cen-

tral Railroad show the following improvement on a Mogul type locomotive with 19-inch × 26-inch cylinders :

| | | | |
|---|---|---|---|
| Speed in m. p. h. | 12 | 30 | 36 |
| Cutt-off, inches of stroke | 10 | 8 | 8 |
| Mean effective pressure: | | | |
| Head end: | | | |
| Large tip, 19.6 sq. inches | 84.12 | 45.39 | 47.66 |
| Small tip, 15.9 sq. inches | 80.42 | 41.60 | 42.40 |
| Gain, lb. per sq. inch | 3.70 | 3.69 | 5.26 |
| Per cent gain, m. e. p. | 4.6 | 8.9 | 12.41 |
| Crank end: | | | |
| Large tip | 86.95 | 47.28 | 46.8 |
| Small tip | 83.28 | 42.74 | 42.2 |
| Gain, lb. per sq. inch. | 3.67 | 4.54 | 4.60 |
| Per cent gain, m. e. p. | 4.5 | 9.76 | 11.65 |

The relation between back pressure and draft, or as it may be termed the draft efficiency, is fully discussed in an



*Original arrangement.* *Modified arrangement.*

Fig. 4. — Modifications necessary in a U. S. R. A. Mikado type locomotive for the application of an annular-ported nozzle.

article on improving draft efficiency which was published on page 499 of the September 1930, issue of the *Railway Mechanical Engineer.* Figure 1 illustrates a typical chart showing such relation. It is evident if the steam flow per square inch of nozzle area is reduced, as would occur if nozzle area were enlarged, resulting in a decrease in back pressure, that without change in the type of nozzle, there would be a reduction in draft produced. Draft requirements increase with increase in combustion demands as the engine is worked harder and the steam demands are therefore increased.

Maximum boiler capacity of a locomotive is dependent upon the ability to supply adequate draft for combustion, and the transfer of heat released through radiation, conduction and convection in evaporating water and superheating the steam. The better the efficiency of the draft-producing medium, the greater the maximum draft that can be produced and consequently the higher the combustion rate that can be sustained. Higher combustion rates, resulting in greater heat release per cubic foot of firebox volume, mean higher firebox and gas temperature and, with the ability to support these higher combustion rates, the maximum limit to boiler capacity becomes the ability to utilize this heat release through heat transfer in evaporating water and superheating steam, i. e. steam production.

The maximum boiler capacity has an important bearing on locomotive output as it limits not only the drawbar pull at speed (the horsepower output), but also influences the drawbar pull at all but relatively low speeds. The percentage of boiler output at various piston speeds is illustrated in figure 2. This was developed from data appearing in various Pennsylvania test plant bulletins, and is fairly representative of what is and may be expected, under a uniform trend of decreasing evaporation per pound of coal with increasing firing rates in pounds of coal per square foot of grate area per hour. Momentary in-

TABLE II.

**Improvement in boiler output and consequent locomotive output, effected by redrafting—Missouri Pacific three-cylinder 2-8-2 locomotive.**

| Test. | Test. designation. | Piston speed, ft. per min. | Evaporation, moist steam per hour. | Drawbar pull. | Indic. H. P. | Least back pressure. | Tractive force on m. e. p. |
|---|---|---|---|---|---|---|---|
| Original front end arrangement—6 1/4-inch open type nozzle | | | | | | | |
| 6906 | 80-50-F | 408 | 28 445 | 41 154 | 1 863 | ... | ... |
| 6904 | 160-43-F | 816 | 42 799 | 26 918 | 2 501 | 13 | 31 206 |
| P. R.R. I-1-s stack—7-inch basket bridge type nozzle | | | | | | | |
| 6914 | 60-80-F | 306 | 51 924 | 52 202 | 2 225 | 6 | 55 524 |
| 6913 | 80-81-F | 408 | 53 924 | 55 403 | 2 356 | 7 | 58 793 |
| 6909 | 160-50-F | 816 | 55 768 | 29 788 | 2 677 | 14 | 33 402 |
| 6910 | 160-50-F | ... | 47 148 | 29 883 | 2 643 | 9 | 32 976 |
| P. R.R. I-1-s stack—7-inch four-projection type nozzle | | | | | | | |
| 6925 | 40-85-F | 204 | 34 504 | 61 847 | 1 364 | 1 | 68 076 |
| 6924 | 80-81-F | 408 | 52 616 | 54 088 | 2 356 | 8 | 58 793 |
| 6921 | 120-59-F | 612 | 51 974 | 42 330 | 2 752 | 11 | 45 873 |
| 6917 | 160-60-F | 816 | 59 920 | 35 488 | 3 141 | 17 | 39 191 |
| 6916 | 160-50-F | 816 | 48 925 | 32 112 | 2 868 | 12 | 35 785 |
| 6926 | 160-60-F | 816 | 61 680 | 35 375 | 3 117 | 17 | 38 892 |

Limit of evaporation reached:
6 1/4-inch open type nozzle—48 000 lb. per hour.
7-inch basket bridge nozzle—55 000 lb. per hour.
7-inch four-projection type nozzle—61 680 lb. per hour.

creases from the relative output shown by figure 2, can be obtained by forcing combustion through the use of the blower or by « swapping » water for steam, but the curve indicates what can normally be expected.

The effort to increase maximum boiler output through improvement in draft production by selection of draft appliances is well illustrated by the tests made with the Missouri Pacific three-cylinder Mikado type locomotive No. 1699 on the Altoona test plant. Table II gives the data from these tests and figure 3 indicates the gain in drawbar pull, which results from an ability to support combustion adequately so as to supply steam to permit working the engine.

Figure 1 shows clearly that as we increase the peripheral surface of the exhaust steam jet and serrate or « nick » the skin surface, we increase the draft per pound of back pressure, which is the draft efficiency.

This is further substantiated by another quotation from Mr. Goodfellow's remarks, previously referred to: « The multiple point nozzle will produce the same draft as the present standard four-projection nozzle with approximately 40 % less back pressure. This figure is also based on tests made on another of the same class of locomotive » (Pennsylvania I-1-s class). That the character of the nozzle insofar as its shape, distribution of steam jet and peripheral surface determining its entraining power, becomes the essential factor in effecting this draft-efficiency improvement, where the work demands are fixed by the gas resistances and necessity for self cleaning, is reflected by a further remark of Mr. Goodfellow. « The type of front end arrangement using a barrel netting and shield, has no advantages or disadvantages over the present standard type from the standpoint of locomotive performance. If its use is to be justified, it must be on the ground of better and cheaper maintenance and inspection. »

It will be noticed from figure 1 that as the back pressure increases there is a dropping tendency to all of the draft curves and, if the experiments were carried far enough, it would be found that no increase in draft would result from further increases in back pressure. In fact, it is probable that there would be a decrease, as indicated by the dotted extension to the curves. This is due to some probable application of the well known law of diminishing returns, or to the fact that the velocity of jet flow increases rapidly, then tapers off gradually, so that above about 11 or 12 lb. back pressure the increase in velocity per pound of back pressure increase is quite small.

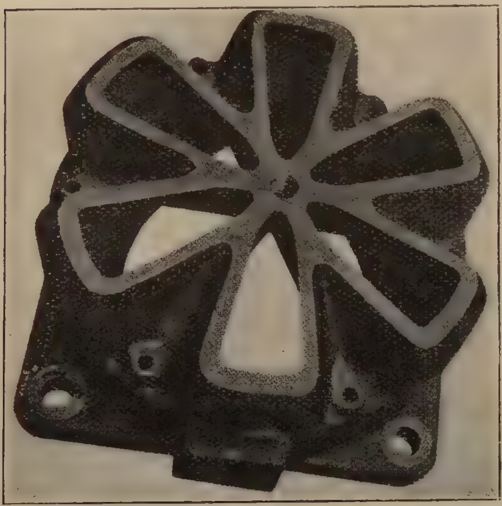


Fig. 5. — The annular-ported nozzle.

The action of a steam jet on the gases in the smokebox may be likened to that of a jet of water discharged into a vessel of water. The density of hot smokebox gases and exhaust steam are approximately the same, so that the conditions are analogous. The motion produced by the discharging jet on the stationary body will be observed to be one of eddy action, and if the discharging jet is broken or nicked, the eddy action is more pronounced. The eddy action is a function of jet velocity and form characteristic, while the spread of the jet is due to uniform volume following at a decreasing velocity. This in essence is the underlying theory of exhaust jet draft production. Its application is unfortunately not as simple owing to the difficulty of observing and recording action in the smokebox of a locomotive.

The article in the September, 1930, issue of the *Railway Mechanical Engineer,* referred to above, gives in detail what may be expected of the annular-ported nozzle in improving draft efficiency. It also presents the principles by which it may be applied to a locomotive. Figure 4 shows the modification required in the front end of a United States Railway Administration heavy Mikado-type locomotive to use the annular ported nozzle, shown in figure 5, in accordance with these principles. In figure 6 is shown the horsepower curves developed with the dynamometer car using this nozzle as compared with the result when using a four-projection nozzle and also this output compared with the American Locomotive Company theoretical horsepower curve. These curves indicate that something is accomplished by reducing back pressure and increasing boiler capacity.

In figure 7 is shown an analysis of how reduced back pressure with improved draft, accomplishing increased boiler capacity, brings about an increase in locomotive output as exhibited by the curves in figure 6. There is, as has been pointed out earlier, an increase in drawbar pull by reducing the braking action of the back pressure on the piston. With judicious selection of an exhaust nozzle to bring about increase in maximum boiler capacity, we have available at all piston speeds, and therefore engine speeds, an increase in po-

Engine 1886 — 75 0/0 per cent maximum cut off.
7 5/8-inch cross bridge nozzle.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trip | 2 | 4 | 6 | 8 | 10 | 12 | Av. |
| Date | 3/16 | 3/29 | 3/30 | 4/6 | 4/8 | 4/10 | ... |
| Average temperature | 46.8 | 48.8 | 53.5 | 85.5 | 66.0 | 61.2 | 60.3 |
| Tonnage | 3 410 | 3 467 | 3 445 | 3 579 | 3 469 | 3647 | 3 502.8 |
| Cars | 50 L<br>1 Mty | 50 L | 52 L<br>1 Mty | 52 L | 50 L | 56 L | 51 L<br>0.3 Mty |
| Elapsed time | 1 hour 53 min. | 1 hour 27 min. | 1 hour 52 min. | 1 hour 30 min. | 1 hour 35 min. | 2 hours 6 min. | 1 hour 44 min. |
| Running time | 1 hour 42 min. | 1 hour 27 min. | 1 hour 36 min. | 1 hour 30 min. | 1 hour 35 min. | 1 hour 52 min. | 1 hour 37 min. |
| Mileage | | | | 25.5 | | | |
| Stops | 1 | 0 | 1 | 0 | 0 | 0 | 0.5 |
| Gross ton-miles | 86 955 | 88 408.5 | 87 847.5 | 91 264.5 | 88 459.5 | 92 798.5 | 89 288.9 |
| Gross ton-miles per train-hour elapsed | 46 150 | 60 900 | 47 050 | 60 840 | 55 800 | 44 190 | 51 500 |
| Gross ton-miles per train-hour running | 51 150 | 60 900 | 54 900 | 60 840 | 55 800 | 49 700 | 55 200 |
| Average back pressure | 8.57 | 10.15 | 10.50 | 10.64 | 8.08 | 8.45 | 9.40 |
| Superheat | ... | 614.6 | 609.5 | 599.3 | 593.1 | 596.7 | 602.6 |
| Boiler pressure | 197.2 | 199.3 | 199.45 | 193.1 | 196.5 | 194.5 | 196.7 |
| Draft back of diaphragm | 4.40 | 5.23 | 5.46 | 5.24 | 4.33 | 4.82 | 4.91 |

OPERATION TO FILL OUT POINT — 43 MILES FROM TERMINAL START.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Water, gallons | 10 682 | 9 552 | 10 447 | 10 113 | 9 470 | 11 206 | 10 245 |
| Water, lb | 89 017 | 79 600 | 87 058 | 84 275 | 78 917 | 93 383 | 85 375 |
| Gross ton-miles | 146 630 | 149 081 | 148 135 | 153 897 | 149 167 | 156 821 | 150 622 |
| Water, lb. per 1000 gross ton-miles | 608 | 533 | 587 | 548 | 528 | 595 | 567 |

Engine 1887
12-inch annular-ported nozzle.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trip | 6 | 8 | 10 | 14 | 2 A | 3 A | 7 A | Av. |
| Date | 2/26 | 2/27 | 3/2 | 4/20 | 8/4 | 8/5 | 8/10 | ... |
| Average temperature | 55.5 | 43.16 | 44.5 | ... | 77.5 | 79.25 | 83.7 | ... |
| Tonnage | 3 419 | 3 401 | 3 416 | 3 582 | 3 558 | 3 634 | 3 646 | 3 522.3 |
| Cars | 48 L | 49 L | 49 L | 52 L | 51 L<br>5 Mty | 44 L<br>23 Mty | 52 L | 49.3 L<br>4 Mty |
| Elapsed time | 1 hour 33 min. | 1 hour 40 min. | 3 hours 20 min. | 1 hour 24 min. | 2 hours 1 min. | 1 hour 39 min. | 1 hour 58 min. | 1 hour 56 min. |
| Running time | 1 hour 25 min. | 1 hour 40 min. | 1 hour 45 min. | 1 hour 24 min. | 1 hour 33 min. | 1 hour 20 min. | 1 honr 33 min. | 1 hour 31 min. |
| Mileage | | | | | 25.5 | | | |
| Stops | 1 | 0 | 3 | 0 | 2 | 1 | 2 | 1.3 |
| Gross ton-miles | 87 184.5 | 86 725.5 | 87 108 | 91 341 | 90 929 | 92 667 | 92 973 | 89 818.3 |
| Gross ton-miles per train-hour elapsed | 56 200 | 52 000 | 26 100 | 65 200 | 44 977 | 56 162 | 47 266 | 47 198.3 |
| Gross ton-miles per train-hour running | 61 550 | 52 000 | 49 750 | 65 200 | 58 535 | 69 675 | 59 983 | 59 799.1 |
| Average back pressure | 6.43 | 4.60 | 7.10 | 6.96 | 8.67 | 8.69 | 6.80 | 7.04 |
| Superheat | 626.3 | 608.5 | 625.0 | 636 0 | 607 1* | 605.8* | 595.5* | 623.9 |
| Boiler pressure | 198.7 | 198.3 | 199.4 | 192 6 | 197.7 | 193.3 | 196.6 | 196.7 |
| Draft back of diaphragm | 4.84 | 3.96 | 5.20 | 5.93 | 6 15 | 6.84 | 4.92 | 5.41 |

OPERATION TO FILL OUT POINT — 43 MILES FROM TERMINAL START.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Water, gallons | 11 026 | 8 766 | 12 548 | 11 559 | Over | | 10 457 | 10 871.2 |
| Water, lb | 91 883 | 73 050 | 104 567 | 96 305 | Lexington | | 87 141 | 90 589.2 |
| Gross ton-miles | 147 017 | 146 243 | 146 888 | 154 026 | Branch | | 156 778 | 150 190.4 |
| Water, lb. per 1000 gross ton-miles | 625 | 499 | 712 | 625 | | | 556 | 603.3 |

* Pyrometer found in error and to require recalibrating. Disregarded in average.

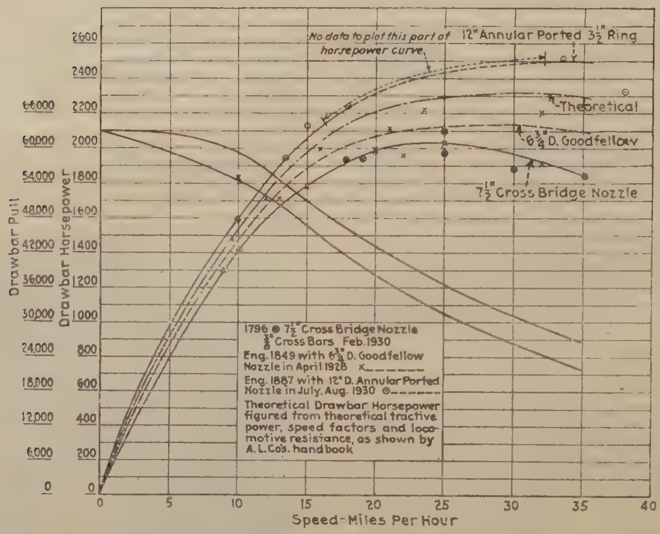



Fig. 6. — Comparison of horsepower curves of locomotives equipped with various types of nozzles with the theoretical drawbar horsepower curve.

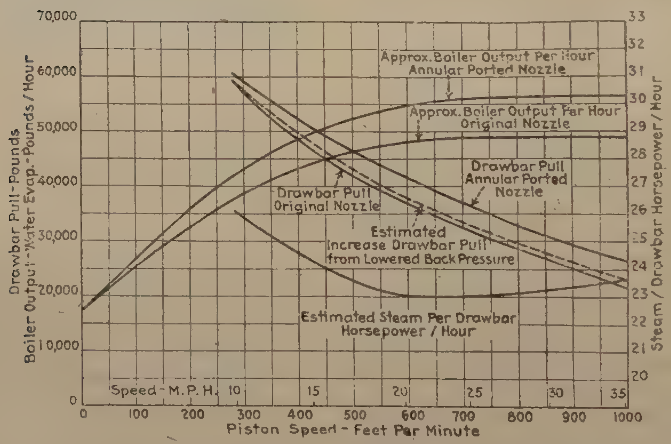



Fig. 7. — An analysis of how reduced back pressure brings about an increase in locomotive output exhibited by the curves in fig. 6.

tential boiler output. The steam economy of the locomotive is not changed by this reduction in back pressure, therefore we have available at all speeds where the locomotive is not worked in or near the corner the ability to work the locomotive at a longer cut-off using this increased available steam to increase the work output or drawbar pull.

No increase in drawbar pull, or an

inappreciable increase, occurs at slow speeds, as the decrease in back pressure is so slight that its effect in increasing mean effective cylinder pressure is almost negligible when working at full cut-off. As the piston speed increases, the back pressure increases and the magnitude of the reduction in back pressure adds to the cylinder output somewhat and appreciably reduces the loss due to the braking action on the pistons. This accomplishes an increase in drawbar pull which has been approximated and assumed to represent a portion of the observed increase as shown by the dotted curve on figure 7.

The use of the annular ported nozzle with its improved draft efficiency enables a higher rate of combustion to be supported adequately and accomplishes an increase in maximum ouput and the output at various speeds. This increase has been arrived at by assumptions from the data developed by standing tests of boiler output with different types of nozzles, and guided by the assumed curve of steam per drawbar horsepower, which appears on figure 7, all analyzed in the light of observed dynamometer-car records.

We have previously shown in figure 2 that there is a relation between the maximum output of the boiler and the output at various piston speeds. It is reasonable, therefore, to assume that if the maximum output is increased, the output throughout the operating range is increased, as shown in figure 7, along the lines of figure 2. Since the steam economy of the locomotive is not affected to any extent by the changes in back pressure through nozzle change which permits operation of the locomotive at an increased cut-off, the balance of the increased drawbar pull recorded by the dynamometer car is the result of this permitted increase in working the locomotive made possible by higher boiler output.

Thus while Mr. Goodfellow states that « these tests showed there was practically no difference in the dry coal or dry steam per indicated dynamometer horsepower with the two different nozzles », there is a marked difference in the work output of a locomotive adequately drafted.

This is in accordance with the findings where the annular ported nozzle has been applied. Fuel economy does not necessarily follow from reducing back pressure, unless the locomotive has been previously underdrafted. There is, as a general result of lowered back pressure and adequate draft production, a marked improvement in the locomotive output, reflected in either higher operating speeds with tonnage trains or increase in the tonnage which can be handled.

The annular-ported nozzle, it might be mentioned in passing, is the same as the multiple pointed nozzle mentioned by Mr. Goodfellow except that the port edges of the latter run in a point to a center opening. The closed central core of the annular ported nozzle is favored, first because it brings the steam out near the periphery where it does its work, second, because it permits modifying the open area by plate application at the center to adjust the nozzle to several similar classes of power and third, because it readily permits of hydrostatically testing steam pipes, superheater units and the exhaust base with the tip in place.

A few intances may be of interest showing improved locomotive operation effected by reduced back presure and bettered boiler capacity through the use of the annular ported exhaust nozzle. An interesting comparison is afforded by the following results from dynamometer tests with two Mikado type locomotives of the same class, Nos. 3188 and 3158, the former of which was equipped with a four-projection nozzle, 6 9/32 inches in diameter with an area of 30.63 sq. inches, while the latter was

equipped with a 14-inch outside diameter annular-ported nozzle with an open area of 41.28 sq. inches. These engines had 23-inch × 32-inch cylinders, 63-inch drivers, 200-lb. boiler pressure and a tractive force of 67 700 lb.

| | Westbound. | | Eastbound. | |
|---|---|---|---|---|
| | 3158 | 3188 | 3158 | 3188 |
| Average speed, m. p. h. | 21.0 | 18.39 | 18.2 | 14.9 |
| Average boiler pressure, lb. | 193.2 | 195.0 | 195.7 | 195.0 |
| Average exhaust pressure, lb. | 6.7 | 8.6 | 6.6 | 8.1 |
| Average front end draft, inches of water. | 9.8 | 10.2 | 9.5 | 10.7 |
| Average tons hauled | 2261 | 2377 | 5918 | 5891 |

Eastbound operation, loaded movement; westbound primarily empty-car movement.

The comparative performance of a United States Railway Administration 2-8-2 B locomotive with the annular-ported nozzle is shown by table III with one of identical characteristics, except that it is equipped with 75 % restricted maximum cut-off rather than a full gear cut-off valve, together with a 7 5/8-inch cross-bridge nozzle. This if anything favors the engine with the cross-bridge nozzle.

Operating characteristics in the territory where the locomotive was operated were such that it was difficult without the aid of a dynamometer car to develop the value of the annular-ported nozzle. Consequently in the absence of a car, the comparison shown in table III was resorted to. The operation out of the terminal in the direction of loaded movement offers a good field for picturing comparative locomotive performance. There is a steady climb for about 26 miles out of the river valley in which the terminal is located to the main line at the top of the watershed. All locomotives handling tonnage trains are worked to capacity and any improvement effected in locomotive steaming or cylinder performance will be reflected in the observed results.

It will be noted that the locomotive equipped with an annular-ported nozzle handled a greater average tonnage than the locomotive equipped with a cross-bridge nozzle in a shorter running time, despite an average of 1.3 stops en route as compared with an average of 0.5 stops with the latter locomotive. This resulted in the delivery of a greater number of gross ton-miles per train-hour of running time, with an average back pressure decrease of 25.1 %, and yet with an increase in draft back of the diaphragm. The only point of superiority in the locomotive equipped with a cross-bridge nozzle is in the average water consumption per 1 000 gross ton-miles and considering the high detention on test 10 with the annular ported nozzle, the showing is not far from equal, when the higher average speed, and therefore work output, is considered. Disregarding test 10, the average for locomotive 1887 is 577 lb. per 1 000 gross ton-miles as compared with 567 lb. for locomotive 1886. Subsequent dynamometer-car tests have developed the comparative data as to horsepower output and tractive force illustrated and analyzed in figures 6 and 7.

There is unquestionably a field for development of exhaust nozzles more in keeping with the demands of modern high powered locomotives. Utilization of the exhaust steam offers a simple device for draft production and one well suited to that task from its characteristic of matching the draft to the combustion demands for the steam requirements. However, as has been pointed out, it acts as a brake, restricting the possibilities of locomotive output. Reduction in back pressure will increase output, and the judicious selection of exhaust nozzles will accomplish not only the relieving of this brake resistance, but will further increase output through increased potential boiler capacity.

[ 625. 2 (0 ]

# Aerodynamical experiments on the exterior form to be given rail motor cars,

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One of the most important technical problems that arise in the study of light rail motor cars intended to run at high speeds on railways is the investigation into the best form for penetrating the air.

Railway literature is, however, almost completely silent as to the form to be given the leading ends of locomotives. This is because that problem is quite a different one. In a train of 500 tons consisting of some ten vehicles, the resistance to air penetration of the locomotive at 120 km. (75 miles) an hour is about 75 kgr. per m² (15.3 lb. per sq. foot) (1) of cross section, that is about 75 kgr. for 8 m² (165.3 lb. for 86.1 sq. feet), which means 1 200 kgr. (2 650 lb) per ton. To this resistance must be added the resistance due to the sides of the trains, the resistance due to the gaps between the vehicles, and finally the rolling resistance, which cause the preceding figures to be quadrupled or quintupled. We therefore arrive at a resistance of 6 to 8 kgr. (1.23 to 1.64 lb. per ton), and any modification of the outer form of the locomotive could not save more than about 0.5 kgr. (1.1 kgr.) of the head-on resistance. The total relative gain would therefore be slight.

On the other hand in the case of a rail car of rectangular section running by itself the resistance of penetration is, again at 120 km. (75 miles) per hour, 600 kgr. (1 322 lb.) for a cross section of 8 m² (86.1 sq. feet) but as the weight of the vehicle is about 12 tons, and the other resistances are small, the resistance to forward motion is in all about 60 kgr. (132.2 lb. per ton) of which 50 kgr. (110 lb.) represents the air resistance. A relatively considerable reduction could be made therefore if this air resistance could be lessened by the use of specially designed forms at the leading end as at the trailing end.

The French Midi Railway Company, which was one of the first to decide to use light rail motor coaches, has endeavoured to find the best form to be given these vehicles by carrying out experiments with small models in the aviation aerodynamic wind tunnel at Issy-les-Moulineaux, in November 1931.

We will now describe the method of operation followed for these experiments and indicate the results obtained.

## I. — Coefficient of similitude.

As a result of many experiments we know that the resistance to forward motion of a body in the air is proportional to the square of the speed, the cross sectional area, the specific weight of the air, and to a coefficient without dimension, $Cx$ characteristic of the form of the body, which can be expressed as follows :

$$R = \frac{a}{2g} S V^2 Cx.$$

(1) Marienfeld-Zossen (1903) trials in which the front end of the vehicle was made in such a way that it could move and transmit its loading to a dynamometer.

A sufficiently accurate idea of the resistance of a vehicle running at a speed V can be obtained by making a test on a reduced scale model of the vehicle in a current of air flowing in parallel streams at V speed.

The component $Cx$ or drag is determined in this way and from it the resistance R of the vehicle is deduced.

A cause of error in the measurements must, however, be noted now. A vehicle on rails moves along near the ground and the air imprisoned between the vehicle and the ground is carried away by the vehicle near its surface, owing to its viscosity, but is at nil speed near the ground.

The curve of the speeds of the air relatively to the vehicle may be reprensentend by AMB (fig. 1).

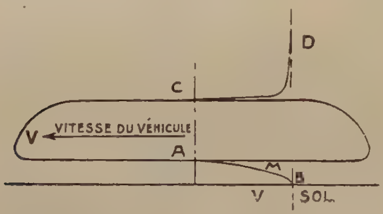


Fig. 1. — Vehicle free to move relatively to the ground.

Curves of the relative air speeds at different points of the cross section.

*Note :* Vitesse du vehicule = Vehicle speed.

Contrariwise, if a fixed vehicle is placed in a stream of air above a thin but very long plane representing the ground (fig. 2), the streams of air are

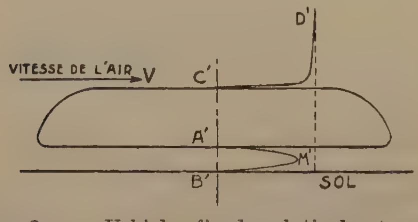


Fig. 2. — Vehicle fixed relatively to the ground, placed in a wind stream parallel to its longitudinal axis.

Curves of the relative air speeds at different parts of the cross section.

*Note :* Vitesse de l'air = Air speed.

disturbed by this thin plane as the air in the immediate neighbourhood of this plane is, by its viscosity, immobilised relatively to the thin plane and therefore relatively to the vehicle, whereas in reality it is well immobile in this area relatively to the ground but at a speed V relatively to the vehicle. A layer of turbulence is in fact introduced which does not exist in practice.

The curve of the relative speeds is approximately A'M'B' and M'B', appreciably less than V through the narrowness of the channel A'B'.

An exact idea of what actually occurs (under reserve of the analogous phenomenon all along the walls of the air tunnel) would be got by considering a belt conveyor moving at the speed of the air current, but this arrangement is impossible to realise in practice.

To make good these difficulties use was made of the so-called « method of images », well known in aerodynamics, to determine the influence of the ground on the aerodynamical resultant of the wings on grounding and which consists in exposing in the air stream a double model, formed of the model properly speaking and by one exactly its image relatively to the ground. We have therefore two symmetrical models separated by twice the distance to the ground.

This arrangement produces between the models in the fluid medium a symmetrical plane which, precisely owing to this symmetry, contains all the trajectories of the fine streams of air in movement (fig. 3). The curve of the relative speeds is A"M"B" with A"M" very close to V. We are therefore much nearer the actual phenomenon in which the relative speed in the ground plane is V (fig. 1) than in the case of the fixed floor (fig. 2) where the relative speed in this same plane was practically nil.

This method is based, on the one hand, on the generally admitted property that through their viscosity the fluid

elements in immediate contact with a solid, accompany the solid without any slip and on the other hand on the fact that in a channel having a symmetrical plane the fluid streams are distributed in such manner that this plane is not cut by any stream but contains an infinite number of thin streams.

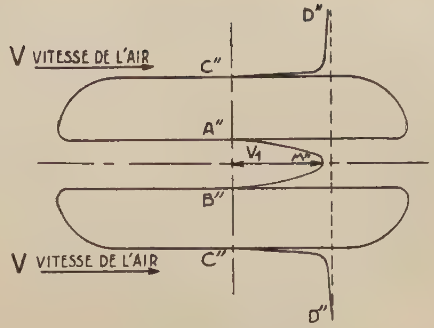


Fig. 3. — Double model placed in an air stream («method of images»).

Curves of the relative air speeds at different points of the cross section.

### II. — Operative method. Aerodynamical tunnel.

The experiments were made in the elliptical tunnel at Issy-les-Moulineaux.

The «Société d'Etudes Aéronautiques» supplied the models and supervised the tests carried out by the Technical Branch of the Aviation Service.

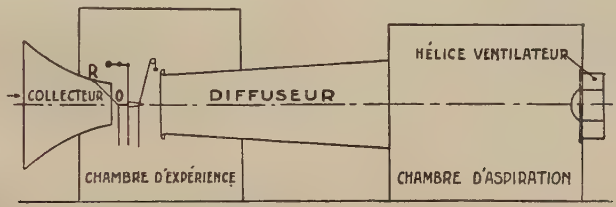


Fig. 4. — Longitudinal section of the elliptical tunnel of the Air Service at Issy-les-Moulineaux.

Collecteur = Collector. — Diffuseur = Diffuser. — Hélice-ventilateur = Fan. — Chambre d'expérience = Test room. — Chambre d'aspiration = Suction chamber.

The elliptical tunnel at Issy has the shape shown in figure 4.

The orifice in the test room has for cross section an ellipse 3 m. × 1.50 m. (9 ft. 10 1/8 in. × 4 ft. 11 1/16 in.) the large axis being horizontal.

A very powerful fan creates a depression in the suction chamber which communicates with an enormous Venturi tube consisting of a collector and a diffuser. The contracted part of the Venturi is open to a closed-in room which contains the measuring appliances and in which the experimenters are stationed.

The measuring appliances include :

1. A Pitot tube, placed outside the zone disturbed by the model, which measures the speed of the air current.

2. An aerodynamical balance by which it is possible on the one hand to carry out the simultaneous measurement of the horizontal and vertical components as well as the magnitude of the air action on the model, and on the other hand, the value of the moments.

The balance consists essentially of a Roberval weighing machine (fig. 5), to one of the pans of which a parallelogram HEFG is connected, the two bars HG and EF of which remain always horizontal and move in the plane of oscillation of the balance. The bar FG carries an arm GK which is always perpendicular

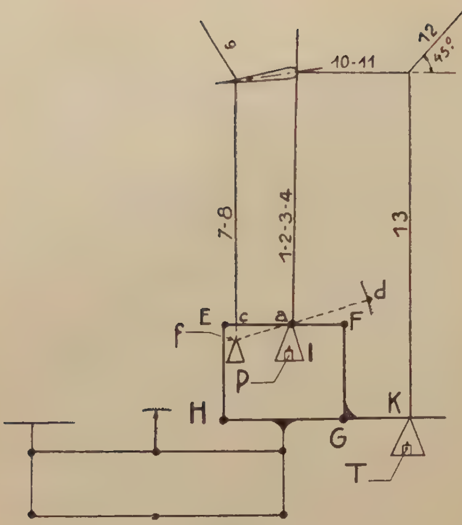


Fig. 5.

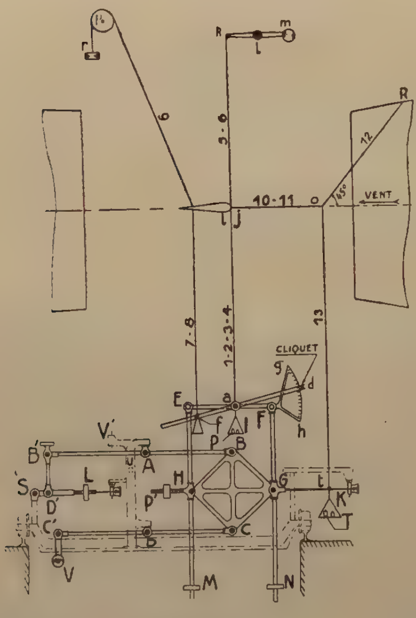


Fig. 6.

to it. One design of balance is shown in figure 6.

The model is now suspended and connected to the balance by two series of vertical wires attached to two distinct points of the pan EF : one (1, 2, 3, 4) connects the front end of the model to point *a*, the other (7-8) connects the trailing end of the model to point *c*. These wires are kept in tension by counterweights and measure the vertical components of the wind and the moments due to the wind, as we will see shortly.

In addition, the model is fixed at the front end by a horizontal wire (10-11) which is connected to the wire (12-13) the upper part of which (12), at 45°, is attached to a fixed point in the tunnel and the vertical part (13) is attached to the lever GK. This wire serves to measure the drag or horizontal resistance to forward motion as the traction on the horizontal wire (10-11) sets up in the vertical wire (13) a component which has the same value owing to the 45° inclination of the wire (12).

*Measurement of the drag and of the vertical component.* — These two measurements are made simultaneously : first of all, the model being in place and the wires tightened by suitable weights, the lengths of the wires and the weights are adjusted on the balance and on the pan of the lever GK so that the model may be horizontal and that the drag wire (10-11) may be horizontal and also the lever GK.

The current of air is then driven through the tunnel.

The whole of the moveable equipment sustains a deformation (fig. 7). The balance and the lever GK are brought back to their initial positions by means of the weight P on the pan I and of the weight T in pan K (fig. 8). It is obvious that P measures the carrying power and T the drag.

However, to the results obtained in this way must be applied a coefficient of correction which depends upon the initial tension of the suspension wires,

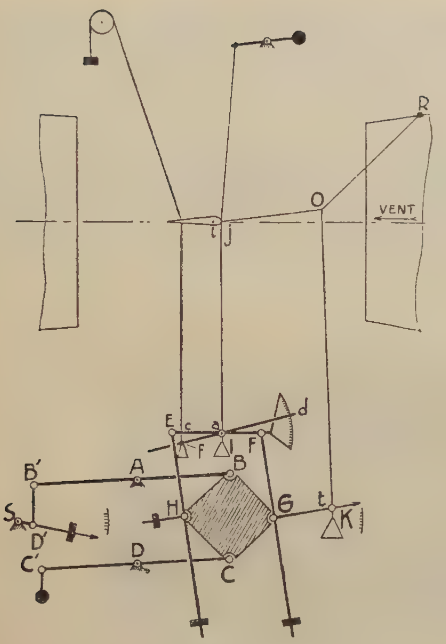


Fig. 7.
*Note:* Vent = Wind.

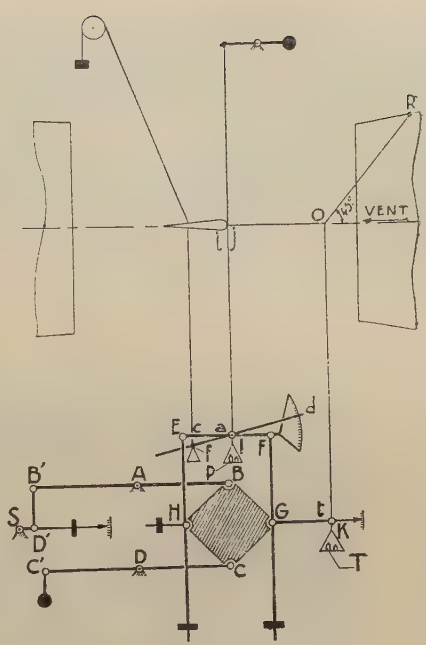


Fig. 8.

their elongation, and the elastic recoil set up in the multiwire system by the drag.

*Measurement of the moments* (fig. 5). — The wire (1, 2, 3, 4) remaining attached to the point *a* of the pan EF, the lever *fd* is released from the pan by moving a latch and the wire is attached to the lever *fd* (oscillating about *a*) which carries a pan attached in line with the wire (7, 8). The weights in the two pans I and *f* (figs. 5 and 6) are adjusted so that the model is horizontal. As soon as the wind blows the whole deflects, the balance and the lever *fd* are brought back to their original position; the product of the weights added at *f*, by the distance *ca*, gives the moment looked for.

### III. — Experiments carried out.

The whole of the experiments were carried out using a current of air at a speed of 101 km. (62.8 miles) per hour = 28 m. (91.8 feet) per second and four models were tried in turn.

The first three had their ends symmetrical, as for convenience of operation it appeared advantageous to have a rail motor car which could run in both directions, i. e. with two driving compartments.

But in order to ascertain the influence of the shape, a fourth model was tested for one direction of running only to which was given a specially designed form to resist as little as possible the forward motion. For very high speeds [(above 130 km. (80.8 miles)] per hour, there appears to be no doubt that forms of this kind must be used if we do not wish to be obliged to use excessively high power, but in this case it will be necessary to give up the idea of running in both directions, and the vehicle will have to be turned for each journey.

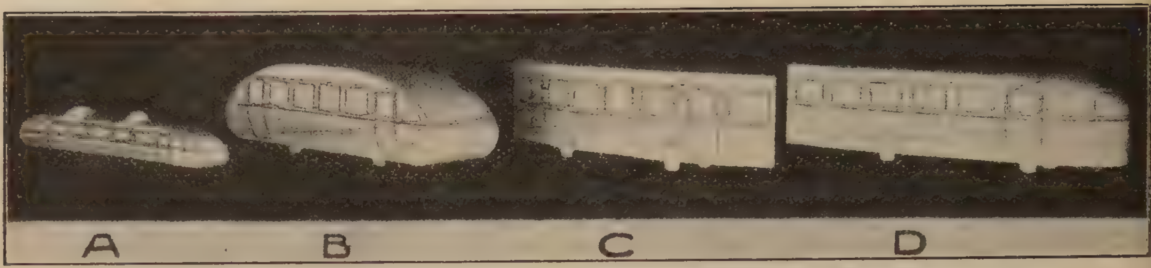


Fig. 9. — Photographs of the four models tested.

Fig. 10. — Photograph of the symmetrical model A with one central raised control compartment look-out.

The two cup shaped projections representing the look-out of the control compartment are not in their proper place in the photograph; the tests were made successively with one and the other, placing them half way along the roof.

The four models tested are shown in figure 9 and are described below :

*Model A.* — The model A to a scale of 3/100 (figs. 10 and 20) consists of two ends, front and back, which are symmetrical, and a central cylindrical part following the cross section of the carriage stock of the French Midi Railway and divided up in turn into 6 equal and detachable sections.

It was therefore possible to reproduce rail motor coaches of different lengths, 25.20 m. (82 ft. 8 in.) — 23.20 m. (76 ft. 1 in.) — 19.20 m. (63 feet) — 17.20 m. (56 ft. 5 in.) — 15.20 m. (49 ft. 10 1/2 in.) and 13.20 m. (43 ft. 4 in.), and to study the influence of length itself on the resistance.

This rail motor coach was designed with a central raised driving compartment represented by a cup-shaped projection, with either a rectangular or elliptical base, above the centre of the rail motor car, whatever the length tested.

The model was suspended in the test room by means of the usual suspension wires, as mentioned previously. A large panel in plywood, rigid, securely held in place in the air current, but without any connection with the preceding system, represented the ground.

The results indicated (fig. 11) give from left to right the resistance to forward motion in kilogrammes of the motor coach for a speed of 101 km. (62.8

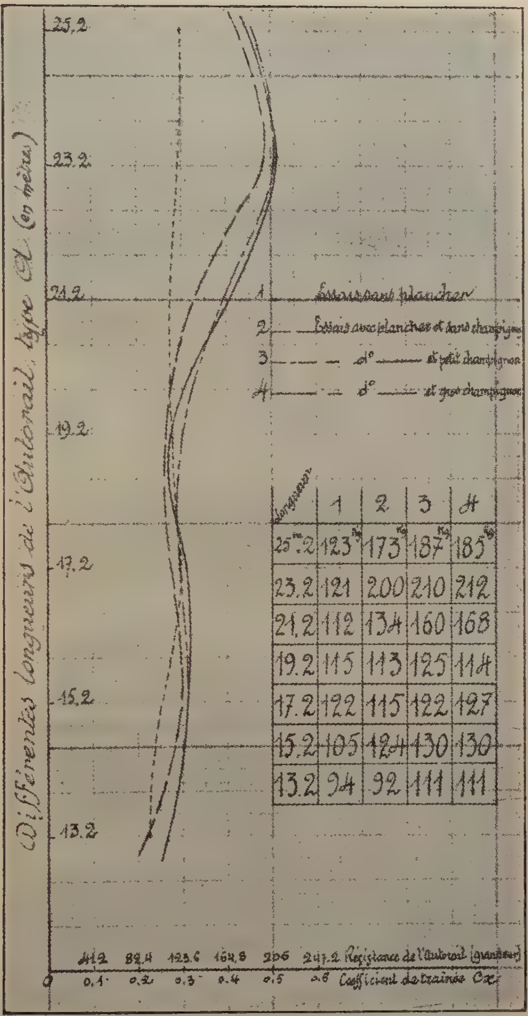


Fig. 11.

*Explanation of French terms :*

Differentes longueurs... = Different lengths of the type A rail motor car (in metres). — Essais sans plancher = Tests without floor. — Essais avec plancher et sans champignon = Tests with floor and no raised look out. — Essais avec plancher et petit (...grand) champignon = Tests with floor and small (...large) look out. — Longueur = Length. — Résistance de l'autorail (grandeur) = Resistance of the rail motor-car (full size). — Coefficient de traînée $C_x$ = Coefficient of drag $C_x$.

miles) per hour, for different lengths and in the following cases :

1. *With the ground present :*

*a*) Fitted with the large look-out;
*b*) With the small look-out;
*c*) Without any look-out.

2. *The ground being some distance away without any look-out.*

It was found that the resistance due to the extension representing the look-out was considerable and that it must not be used; that between 14 and 19 m. (45 ft. 11 in. and 62 ft. 6 in.) the influence of length was negligeable.

This first experiment, however, was not free of errors, for the following reasons :

1. *Resistance of the suspension wires.* — In view of the reduced scale of the model, the resistance of the wires was three times greater than that of the model itself. Under these conditions, the resistance due to the model alone was very difficult to calculate accurately and the different readings taken brought out differences which could not be explained.

2. *Influence of the ground.* — First of all the rigid ply-wood floor had its leading edge cut off square. The results thus obtained were noted; then to avoid the influence of the leading edge on the general resistance, the edge of the floor was bevelled off in order to prevent the plys separating. The measured resistance was doubled after doing this.

Moreover, exploration of the air current showed an appreciable diminution of the speed of the air current near the floor, as was expected and as we mentioned above.

Finally, in order to vary the length of the model, it was necessary to drill holes to allow the wires to pass through the floor, and this, it appeared, set up alterations of the flow.

Fig. 12. — Position of a double model C in the air stream.

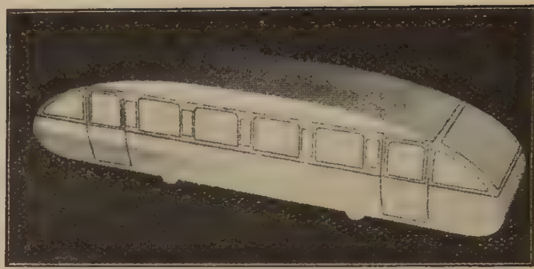

Fig. 13.

It was therefore necessary to change the method of operation for models B-C-D and adopt the double model without floor at practically double the scale (65/1 000 instead of 3/100), so that the uniform length of 13.85 m. (45 ft. 5 1/4 in.) for the rail cars gave the model a length of 0.90 m. (2 ft. 11 1/2 in.).

The double model was arranged horizontally in the air stream as shown in figure 12, the floors of the carriage facing one another, in vertical planes parallel to the centre axis of the tunnel and separated by a distance double that of their distance from the ground.

*Model B* (double). — Model B shown in figures 13 and 20 has symmetrical ends. The width is the same throughout the length but the roof is turned down at the two ends.

The distance apart of the two parts making up the model being 6 cm. (2 3/8 inches), and the speed of the air stream (measured by the average depression in the suction chamber) 28 m. (91.8 feet) per second or 101 km. (62.8 miles) per hour, the following results were obtained :

| | |
|---|---|
| Coefficient $Cx$ . . . . . . . . . | 0.345 |
| Resistance measured by the balance. | 0.612 kgr. |

Applying this result to a railcar of this form, but full size, running at 101 km. an hour, would give a resistance to forward motion of 145 kgr. (319.2 lb.) i. e. 16.8 kgr.per m$^2$ (3.44 lb. per sq. foot) of section.

*Model C* (double). — This model is shown in figures 12, 14 and 20, and in

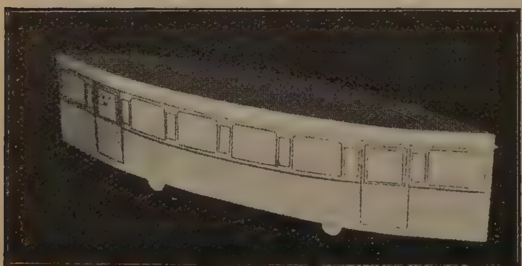

Fig. 14.

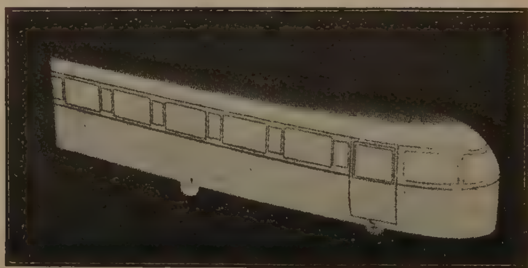

Fig. 15.

plan is spindle shaped, its two ends are symmetrical and its height is the same throughout its length.

The results obtained during the tests are as follows :

| | |
|---|---|
| Coefficient $Cx$ . . . . . . . . . | 0.154 |
| Resistance measured on the balance. | 0.273 kgr. |

The rail car built with this form would give at a speed of 101 km. per hour, a resistance to forward movement of 65 kgr. (133.1 lb.) i. e. 7.60 kgr. per m² (15.56 lb. per sq. foot) of cross section.

*Model D* (double). — The model D shown in figures 15 and 20 is the one that gave the best results as regards air penetration. In plan it has a form resembling that of the body frame of a flying machine; the height is the same over the greater part of the length and the roof is turned down at the leading end.

When tested under the same conditions as models B and C, the results obtained during the tests were the following :

| | |
|---|---|
| Coefficient $Cx$ . . . . . . . . . | 0.106 |
| Resistance measured on the balance. | 0.178 kgr. |

Applying these results to a full sized rail car built to this form we should get at a speed of 101 km. per hour a resistance to forward motion of 42 kgr. (92.6 lb.), i. e. 5.20 kgr. per m² (1.06 lb. per sq. foot) of cross section.

Starting from these results, it was possible to draw down the curves of the aerodynamical resistances for the three types of rail car in terms of the speed.

These curves are shown in figure 16.

### IV. — Discussion of the results.

The results obtained in these tests only take into account the resistance due to the form of the vehicle itself; it is desirable to add to this :

1. The supplementary aerodynamical resistances due to the equipment carried under the frame (bogies, brake gear, motor, etc.) which, in the absence of experimental tests, are supposed to be the same on the three types of rail cars and to be equal to one third of the air resistance due to the body of shape D (1).

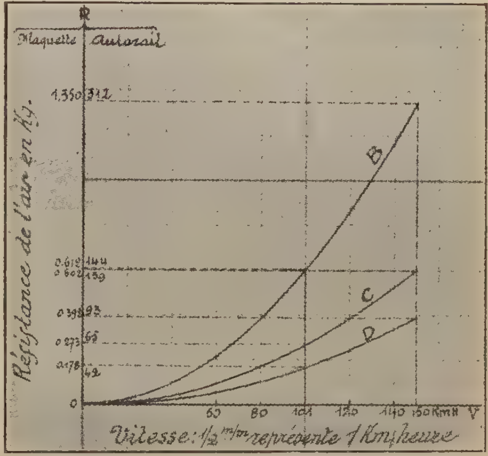


Fig. 16. — Type B, C and D rail cars.

Curves of the aerodynamical resistances of the three models B, C and D and the corresponding rail cars, neglecting other resistances.

Area of largest cross section { rail cars B and C = 8.6 m² (92.6 sq. feet). rail car D = 8.1 m² (87.2 sq. feet).

*Explanation of French terms :*

Maquette = Model. — Autorail = Rail car. — Résistance de l'air en kgr. = Air resistance in kgr. — Vitesse : 1/2 mm. représente 1 km./heure = Speed : 1/2 mm. represents 1 km./hour (*in the original diagram, which is reproduced here at a reduced scale*).

2. The running resistance which can be taken as equal to 1.30 kgr. (2.87 lb.) per ton for a vehicle with roller bearing axle boxes.

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(1) This is simply a hypothesis which is probably exact only when the different fittings are properly grouped together or are given a suitable exterior shape.

The curves of the total resistances for rail cars of types B, C and D weighing 12 tons are approximately those given in figure 17.

By means of these curves the total resistance of such a vehicle running on the level at different speeds can be obtained directly, and the power required to attain each speed can be calculated.

In this way table 1 has been prepared.

TABLE 1.

| RESISTANCES AT SPEEDS OF : | 80 km. (*50 miles*) per hour. | 101 km. (*62.8 miles*) per hour. | 120 km. (*75 miles*) per hour. | 150 km. (*93 miles*) per hour. |
|---|---|---|---|---|
| | kgr. (*lb.*) | kgr. (*lb.*) | kgr. (*lb.*) | kgr. (*lb.*) |
| **Shape B.** | | | | |
| $R_1$-Aerodynamical resistance of the body | 90 (*198.4*) | 145 (*319.7*) | 202 (*445.3*) | 312 (*687.8*) |
| $R_2$-Aerodynamical resistance of the fittings | 9 ( *19.8*) | 14 ( *30.9*) | 20 ( *44.1*) | 31 ( *68.3*) |
| $R_3$-Rolling resistance | 15.6 ( *34.4*) | 15.6 ( *34.4*) | 15.6 ( *34.4*) | 15.6 ( *34.4*) |
| $R_4$-Total resistance | 114.6 (*252.6*) | 174.6 (*385.0*) | 237.6 (*523.8*) | 358.6 (*790.5*) |
| Power absorbed, H.P. | 33 | 65 | 104 | 196 |
| **Shape C.** | | | | |
| $R_1$-Aerodynamical resistance of the body | 40 ( *88.1*) | 65 (*143.3*) | 89 (*196.2*) | 139 (*306.4*) |
| $R_2$-Aerodynamical resistance of the fittings | 9 ( *19.8*) | 14 ( *30.9*) | 20 ( *44.1*) | 31 ( *68.3*) |
| $R_3$-Rolling resistance | 15.6 ( *34.4*) | 15.6 ( *34.4*) | 15.6 ( *34.4*) | 5.6 ( *34.4*) |
| $R_4$-Total resistance | 64.6 (*142.3*) | 94.6 (*208.6*) | 124.6 (*274.7*) | 185.6 (*409.1*) |
| Power absorbed, H.P. | 19 | 35 | 55 | 101 |
| **Shape D.** | | | | |
| $R_1$-Aerodynamical resistance of the body | 26 ( *57.3*) | 42 ( *92.6*) | 60 (*132.3*) | 93 (*205.0*) |
| $R_2$-Aerodynamical resistance of the fittings | 9 ( *19.8*) | 14 ( *30.9*) | 20 ( *44.1*) | 31 ( *68.3*) |
| $R_3$-Rolling resistance | 15.6 ( *34.4*) | 15.6 ( *34.4*) | 15.6 ( *34.4*) | 15.6 ( *34.4*) |
| $R_4$-Total resistance | 50.6 (*111.5*) | 71.6 (*157.9*) | 95.6 (*210.8*) | 139.6 (*307.7*) |
| Power absorbed, H.P. | 14.8 | 27 | 42 | 76 |

*Influence of the distance from the ground.* — The preceding tests carried out with a space of 60 mm. (2 3/8 inches) between the models have given for model D, for example, a coefficient $Cx$ of 0.106.

The tests for this same model were repeated by increasing the interval to 70 mm. (2 3/4 inches) and the coefficient $Cx$ fell to 0.096. It therefore appears desirable to increase as much as possible the height of the rail car above the track.

This conclusion which appears paradoxical is due to that these tests having been made with plain models without any accessory fittings under the body, such as wheels and axles, brakes, reservoirs, etc. The accessories set up considerable resistance, and it is probable that it is desirable to enclose them by outside plating extending the body

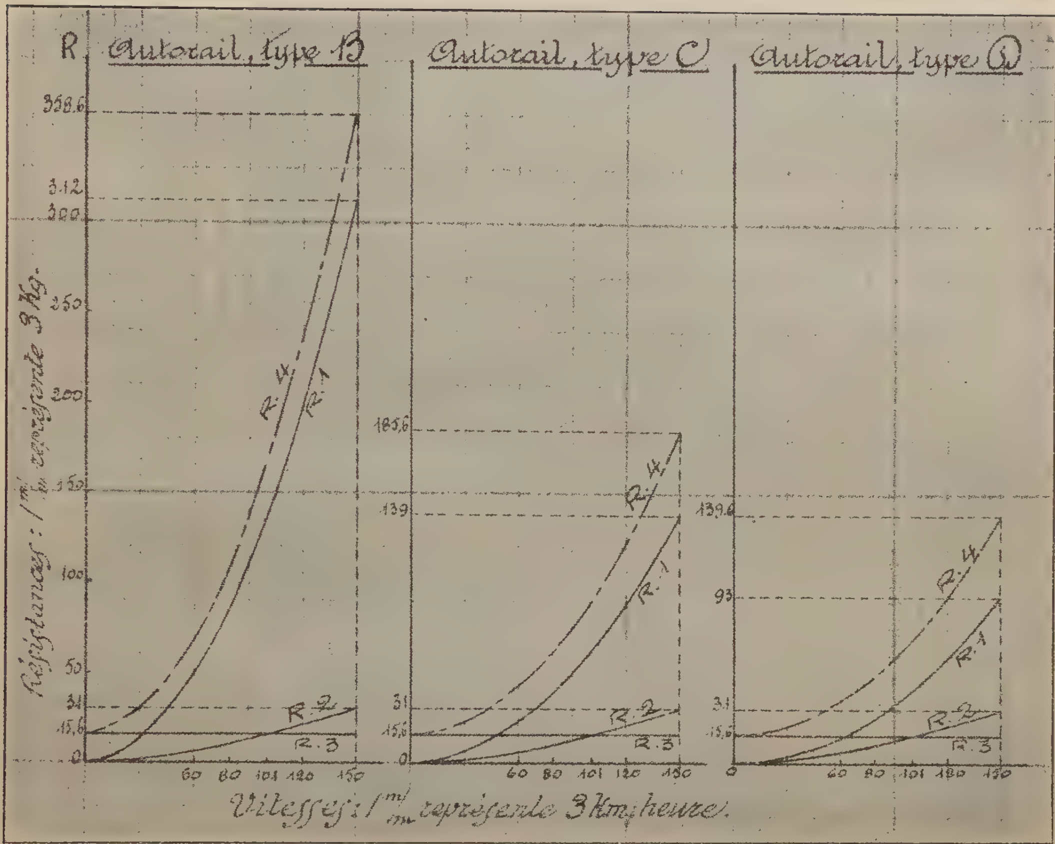


Fig. 17. — Total resistance to forward motion for vehicles weighing 12 tons.

R. 1 : Main aerodynamical resistance of the body.
R. 2 : Main aerodynamical resistance of the accessories.
R. 3 : Rolling resistance.
R. 4 : Total resistance.

*Explanation of French terms :*

Autorail = Rail car. — Resistances : 1 m/m. représente 3 kgr. = Resistances : 1 m/m. represents 3 kgr. — Vitesses : 1 m/m. représente 3 km./heure = Speeds : 1 m/m. represents 3 km. per hour.

(Note : *These ratios do not apply to the above diagram, as the original is reproduced at a reduced scale.*)

downwards as near to the ground as possible, as the resistance of a plate of this kind, when properly profiled, can be less than that of all the above mentioned fittings arranged without order under the body and designed without any care in the way of obtaining the best aerodynamical form.

### V. — **Additionnal experiments.**

In order to obtain further information, the Engineers of the « Société d'Etudes Aéronautiques » carried out the various tests described below :

A. — *Aerodynamical braking.* — With high-speed rail cars, it may be desirable to use an additional braking which could

be set up artificially by an aerodynamical resistance obtained by adding to the trailing end of the vehicle vanes normally folded away into the body so as not to offer any resistance (fig. 18, position *a*), but which could be opened out at the moment of applying the brakes (fig. 18 positions *b*, *c*, and *d*). These vanes are built up of smooth plates : they are at right angles to the running plane and at an obtuse angle between themselves in the direction of running.

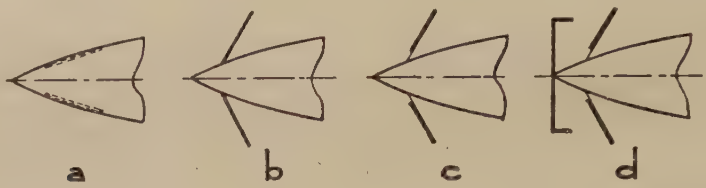


Fig. 18.

The tests carried out at 101 km. (62.8 miles) per hour on models C and D gave the results shown in table 2.

TABLE 2.

| — | Model C | | Model D | |
|---|---|---|---|---|
| | Coefficient $Cx$. | Resistance. | Coefficient $Cx$. | Resistance. |
| | | kgr. (*lb.*) | | kgr. (*lb.*) |
| With two symmetrical brakes without slots (position *b*) . . . . . . . . . . . | 0.521 | 0.927 (*2.044*) | .. | ... |
| With two symmetrical brakes with slightly open slots (position *c*). . . . . . . . | 0.517 | 0.919 (*2.026*) | 0.928 (*2.046*) | 1.560 (*3.439*) |

Applying these results to a full sized rail car of the D type for example we find a resistance to forward movement of 368 kgr. with two brakes and slots slightly open. The resistance to forward motion for this rail car without brake was 42 kgr. so that the aerodynamical braking effort was 326 kgr. (718.7 lb.). At 150 km. (93 miles) an hour, it would be 697 kgr. (1 536.6 lb.).

The resistance of the brake vanes can be still further increased if a slot is left to allow the air to flow along the side walls and another cross vane in the form of a cupel like a hydraulic turbine bucket is placed beyond them (fig. 18, position *d*).

This additional brake device which only depends upon the form and not upon the weight of the vehicle is evidently only interesting in the case of extra light rail cars, but it appears to merit notice.

B. — *Turning over and couple of gyration.* — It was equally interesting to note the influence of a violent wind acting on the side and the effect of running onto curves.

Tests have been carried out by inclining the models in the air current (changing the angle of incidence):

In this case the formulæ giving the turning over component and the moment

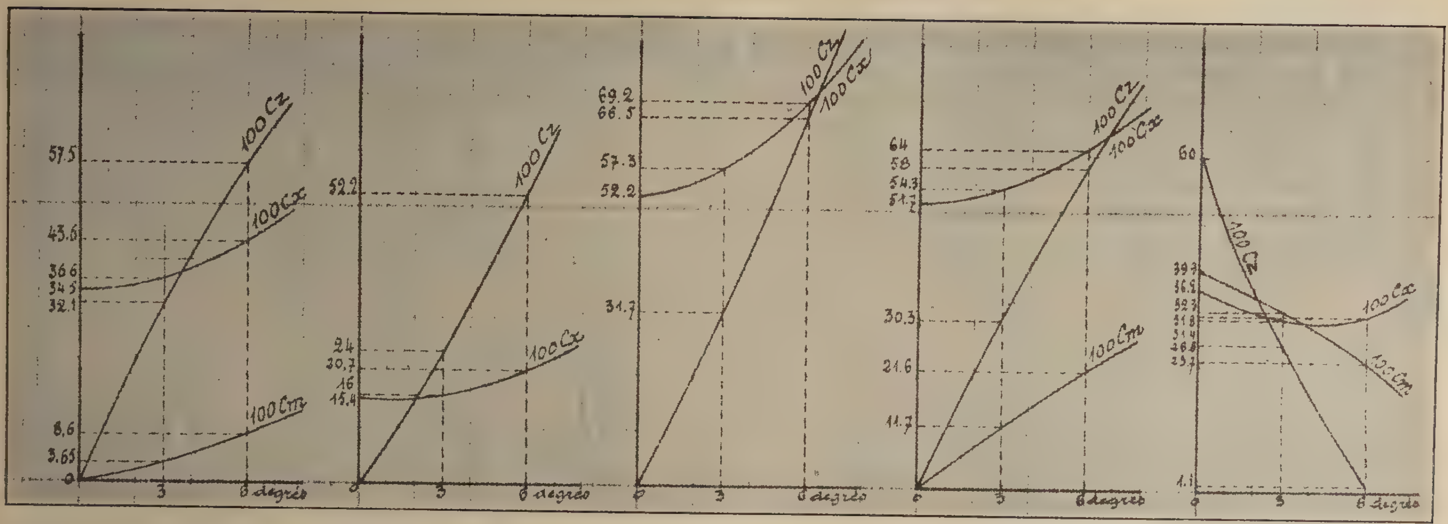


Fig. 19. — Value of the coefficients 100 $Cx$, 100$Cz$ and 100 $Cm$ as a function of the orientation of the vehicle on entering curves.

relatively to the striking edge, resemble the formula of pure resistance and we have :

— Turning over component $F = \frac{a}{2g} \times Cz \times S \times V^2$ in which $Cz$ is a coefficient without dimensions.

— Moment relatively to the striking edge : $M = \frac{a}{2g} \times Cm \times L \times S \times V^2$ in which $Cm$ is also a coefficient without dimensions and L the length of the model, that is 0.90 m. (2 ft. 11 1/2 in.), corresponding to a rail car length of 13.85 m. (45 ft. 5 1/4 in.).

The results obtained are given in table 3 and are shown graphically by the curves of figure 19.

These results show that the vehicles are perfectly stable and there is nothing to fear from wind nor when running onto curves.

TABLE 3.

| ANGLES OF INCIDENCE. | $Cx$ | $Cz$ | $Cm$ | M in Kg.-M at 101 km./h. *(in foot-pounds at 64.8 m. p. h.)* | For the rail car of this type: M in Kg.-M. at 101 km./h. *(in foot-pounds at 64.8 m. p. h.)* |
|---|---|---|---|---|---|
| | | | **Model B.** | | |
| 0 . . . . . . . . | 0.345 | 0 | 0 | 0 | 0 |
| 3 . . . . . . . . . . | 0.366 | 0.321 | 0.0365 | 0.058 *(0.419)* | 213 *(1 540)* |
| 6 . . . . . . . . . | 0.436 | 0.575 | 0.086 | 0.137 *(0 991)* | 502 *(3 630)* |
| | | | **Model C.** | | |
| | | 1. Without brakes (Position II, fig. 20). | | | |
| 0 . . . . . . . . . | 0.154 | 0 | ... | ... | ... |
| 3 . . . . . . . . . . | 0.160 | 0.24 | ... | ... | ... |
| 6 . . . . . . . . . . | 0.207 | 0.522 | ... | ... | ... |
| | | 2. With two brakes and no slot (Position III, fig. 20). | | | |
| 0 . . . . . . . . . | 0.521 | 0.330 | ... | ... | ... |
| 3 . . . . . . . . . . | 0.573 | 0.317 | ... | ... | ... |
| 6 . . . . . . . . . . | 0.692 | 0.665 | ... | ... | .. |
| | | 3. With two brakes and slots slightly open (Position IV, fig. 20). | | | |
| 0 . . . . . . . . . . | 0.517 | 0 | 0 | 0 | 0 |
| 3 . . . . . . . . . . | 0.543 | 0.303 | 0.117 | 0.187 *(1.352)* | 682 *(4 933)* |
| 6 . . . . . . . . . . | 0.614 | 0.580 | 0.216 | 0.345 *(2.495)* | 1 260 *(9 113)* |
| | | 4. With one dissymmetrical brake (Position V, fig. 20) | | | |
| 0 . . . . . . . . . | 0.362 | 0.600 | 0.399 | 0.638 *(4.614)* | 2 329 *(16 845)* |
| 3 . . . . . . . . | 0.314 | 0.266 | 0.323 | 0.516 *(3.732)* | 1 885 *(13 634)* |
| 6 . . . . . . . . . . . | 0.318 | 0.011 | 0.237 | 0.379 *(2.741)* | 1 383 *(10 003)* |

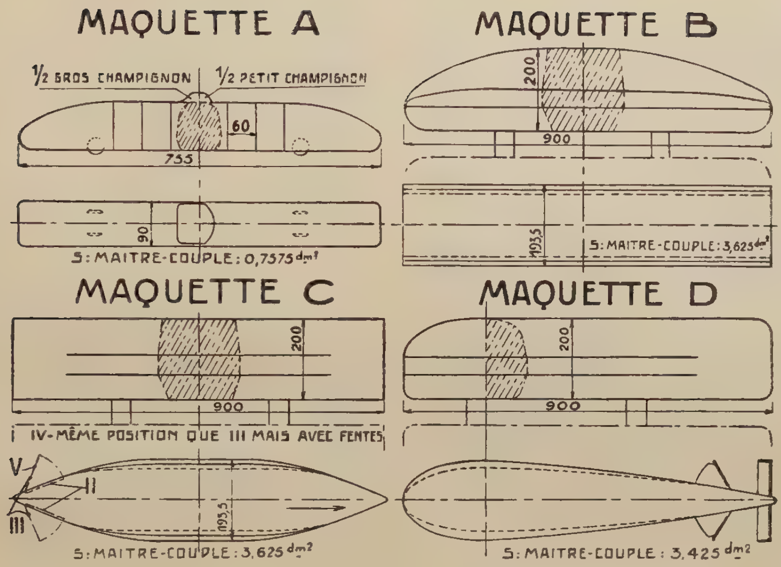


Fig. 20.

*Explanation of French terms:*

Maquette = Model. — 1/2 gros champignon = 1/2 large look-out. — 1/2 petit champignon = 1/2 small look-out. — Maître-couple = Cross section. — Même position que III, mais avec fentes = Same position as III, but with slots.

## Conclusion.

The above tests have only been made on three patterns of models; it is not possible, therefore, to decide from them the optima exterior form in building a rail motor car : they only show the considerable influence of this form on the power necessary to propel the rail motor car, as soon as the speed exceeds 100 km. (62 miles) an hour, and the value of such tests.

The reduction of the power is not only advantageous by the reduction of fuel comsumption it gives, it is also required by the capacity of internal combustion motors of the automobile type, the power of which is limited at the present time to 120 H. P. in the case of petrol motors and 100 H. P. approximately for the light Diesel type.

Naturally the results of the aerodynamical tests can not be put into practice integrally; it is desirable to find a compromise between the advantage of a given profile, the building facilities, the interior arrangement, and especially the convenience of operation.

Consequently in most cases the great advantage of a double driving compartment, making it unnecessary to turn the vehicle at the terminal points, will involve the aeroplane body form being abandoned and a symmetrical spindle shaped form being adopted.

However, if speeds of the order of 150 km. (93 miles) an hour are desired, it will probably be necessary to give up symmetrical designs and to adopt a vehicle having the form of the body frame of an aeroplane.

[ 625 .13 (.42) ]

# The ventilation of London Tubes.

*(The Railway Engineer.)*

Extensions to the underground group of railways in London are proceeding in several directions, as is common knowledge. The opportunity thus presented is being taken to attack the ventilation problem from a new angle. Particularly in the Southgate extension of the Piccadilly Railway, where there will be about four miles of new tunnel, arrangements are being made which differ from the former practice in the existing tubes. The latter have, of course, developed piecemeal, and ventilation methods have had to be adopted to meet the conditions as they arose.

Ventilation is required in underground railways from the point of view of heat removal rather than air pollution. The conditions are quite different from those affecting the ventilation of a public vehicular tunnel.

Numerous tests have shown that even in the rush hours, and without large ventilating plants, the air in the under-

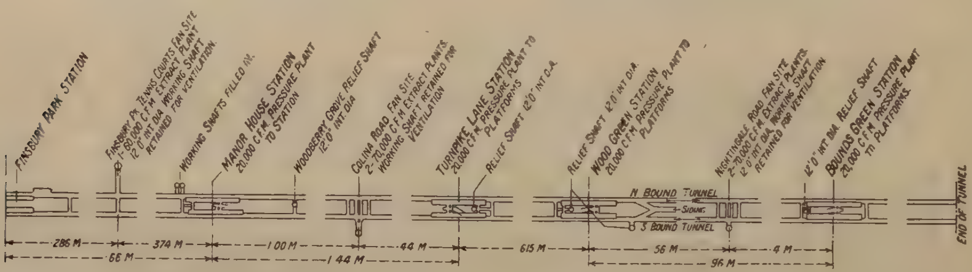


Fig. 1. — Diagram of line, showing location of ventilating shafts.

ground railway tunnels contains practically no more carbon-dioxide than the normal outdoor atmosphere, and, of course, no carbon-monoxide. Moreover, the air in the tunnels is remarkably dry, and this is unfavourable to bacteria. Not only do measurements show that bacteriological activity is very low underground, but also the health of the staff permanently employed there is unusually good. In epidemics the infection rate of the underground staff compares very favourably with that of workers in other occupations. Possibly the slight production of ozone by the electrical apparatus employed acts to some extent as a germicide.

Heat is introduced into the tubes to some extent by radiation from the passengers, but in the main by the electrical energy supplied to the trains. A few moments' thought will show that the whole of the energy received by the trains appears eventually in the atmosphere as heat, principally by way of friction, and it is this energy which has to be removed by the ventilating air in order to prevent a continuous rise of temperature. Within recent years the amount of energy supplied has been largely increased, not only due to the additional train miles operated, but also because of the increased acceleration necessitated by revised schedules. The

ventilating air supplies to the existing tubes have been increased from time to time in order to cope with this condition, but in spite of such steps, although the average temperature drops to some extent during the winter months, until recent years it did not return to quite such a low figure as in the previous year. This phenomenon is being closely watched and the necessary steps to meet it are well in hand.

In the early days of tube operation the

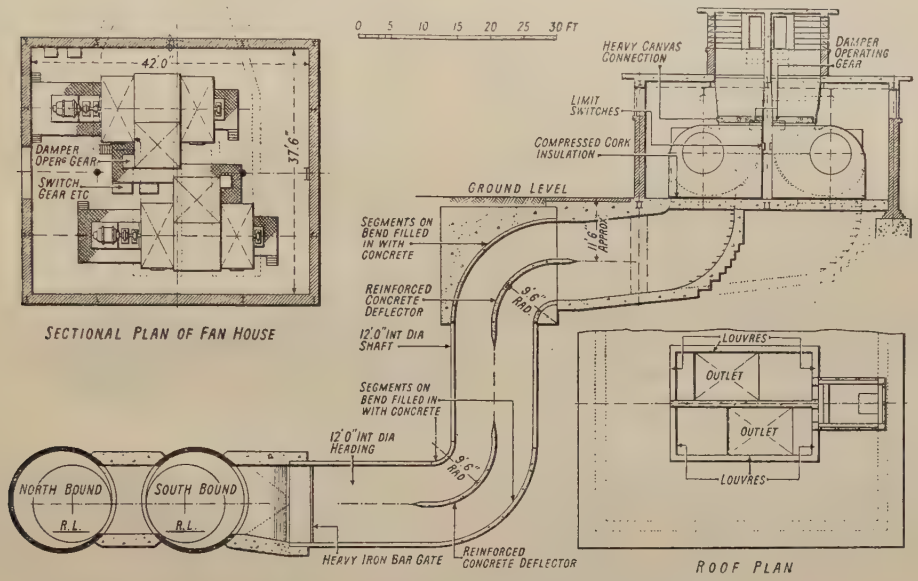


Fig. 2. — Typical arrangement of extraction fan house, being that at Colina Road.

problem was not wholly recognised. On the Central London Railway, for instance, which was one of the earliest deep underground railways, operation was commenced without any special ventilation. As the temperature began to rise it was decided to remove the heat by passing a current of air through the tube during non-running hours, and for this purpose a large fan, with a capacity of 200 000 cubic feet per minute, was put down at Wood Lane, where the tunnel comes up to the surface. The end of the tunnel was closed after traffic had ceased at night and the fan operated as an exhauster. Doors were constructed at the various stations to prevent air entry when the fan was operating. The majority of the air was thus caused to pass through the whole tunnel, entering at the Bank, which was then the terminus. Unfortunately, however, the air current reached normal tunnel temperature during the first parts of its passage through the tunnel so that it was quite ineffective to remove heat from the sections nearer the fan. Subsequent ventilation was made more localised, with fans at most of the stations. By adding to the number and capacity of these fans, it has been possible to maintain comfortable temperatures, but the energy required for ventilation has increased very considerably.

The later tube railways have been provided with ventilating plant from

their inception. Pressure supplies have been used in some cases, but the exhaust system is now favoured. With the pressure system there are cold spots formed at the fan deliveries, particularly noticeable in the winter, and there is a tendency for the warm air to find an outlet through the station passages and booking halls. It is undesirable for a passenger entering the premises to be met by a stream of warm air; he should preferably enter along an inlet current. By exhausting from points near or at the tunnel junctions to the stations the latter are maintained as the freshest and most pleasant parts of the system. This is the general principle now adopted in the existing tubes, with variations to meet local conditions, particularly in the avoidance of noticeable draughts, as far as possible.

The growth of air movement involved in the ventilation of the present tube lines is illustrated by the following figures, which give the total capacity of the fans installed :

End of 1927 : 1 170 000 cubic feet per minute.

End of 1929 : 1 639 000 cubic feet per minute.

End of 1931 : 2 157 000 cubic feet per minute.

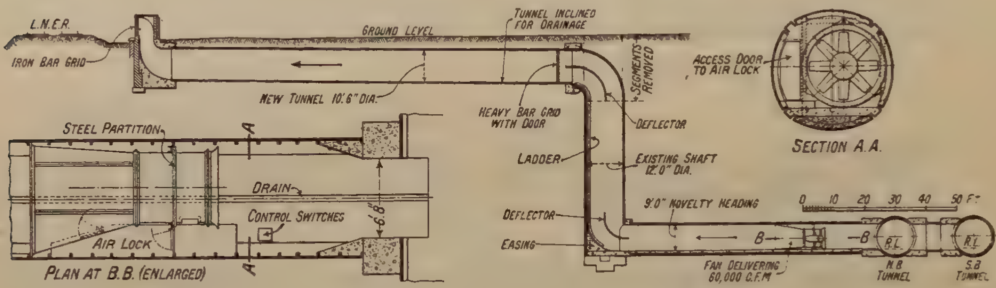

Fig. 3. — 60 000 c.f.p.m. Aeroto fan for extraction, at Finsbury Park.

Special attention has been given to the whole question of the ventilation of the new extensions to the underground system. As the Southgate extension of the Piccadilly line from Finsbury Park to Cockfosters contains the longest new tunnelling, we propose to confine our attention at present to the arrangements which have been made for the solution of the problem on this line. Compared with the existing underground system, it is, of course, only a short line. The fans situated between tunnel stations alone would suffice to change the air in the extension four times an hour. Nevertheless there are several features of interest in the new work.

The construction of the four-mile tunnel was pushed forward very rapidly. It was commenced in October, 1930, and finished at the end of 1931. At one period of construction no fewer than 24 shields were in operation. In order to handle the excavated material, several working shafts were sunk, besides those on the station sites. It has been found impossible to retain all the working shafts for ventilating purposes, as some of them were located on semi-private land and have had to be filled in. Three such shafts have, however, been allocated to ventilation, and these fortunately are situated near the middle of the tunnel between alternate stations, as will be seen in the drawing that gives a general plan of the extension. They are 12 feet in diameter and are connected to enlarged sections of the tunnel, there being also

cross galleries of ample area communicating between the two tunnels for the up and down lines respectively. Very easy

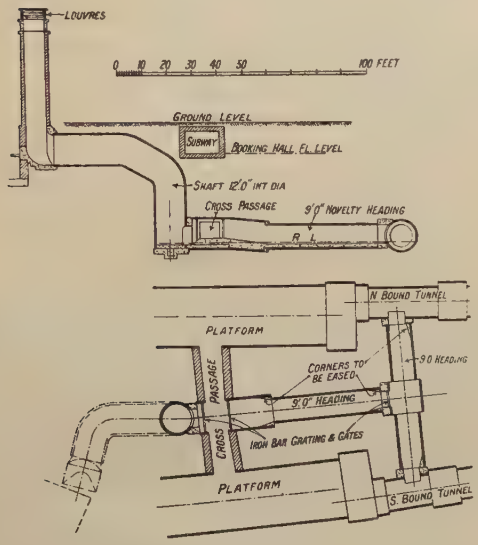


Fig. 4. — Plan and elevation of relieving shaft at Turnpike Lane Station.

bends and deflector guides are provided both at the bottom and top of the shaft, and the average velocity of the air has been calculated not to exceed 1 200 feet per minute. In each case duplicate 70 000 cubic feet per minute fans will be provided at the surface, and it is anticipated that one of these will run continuously, while the other will be put into commission for such periods as may be necessary to prevent the average temperature of the tunnel rising. The fans will be supplied by James Howden Limited, and be fitted with louvre dampers. They will run at 480 r.p.m. and be direct driven by three-phase motors of high starting torque type, rated at 30 H. P. each. Watford electrical starters are being employed, arranged to give simple selection of the fans, and interlocked with the dampers. Special « évasé » dischargers are provided, but with louvre coverings, and every care is being taken to minimise any noise which may result from the operation of these fans. They are necessarily located in a very thickly populated district, and these steps have

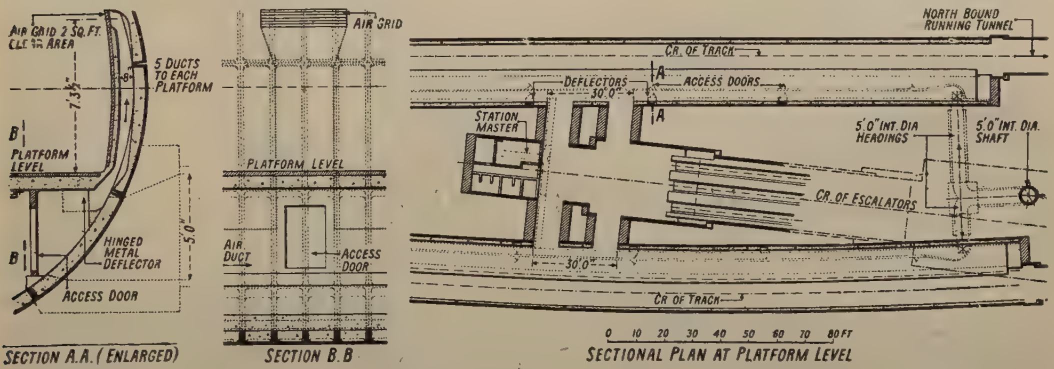


Fig. 5. — Arrangement of local platform ventilation by means of which fresh air is injected through a special 5-foot shaft, Manor House Station.

been taken to forestall any possible complaints from owners of surrounding property. The inter-station fan plant near Finsbury Park is unusual in that it is located underground in the park itself. Limitations of space, and considerations of cost of the fan house, led to the adoption of an axial flow fan in this instance. This is a compact type of high-efficiency propeller fan, but all the other plants are of the more usual centrifugal type.

Several working shafts have also been experimentally retained on station sites in addition to those required for escalators and access purposes. These are termed « relieving shafts », and will function to reduce the velocity of the air through the public passages. Since they are clear of obstruction, it is anticipated that more than half the total air being handled at the stations will enter through them. In addition, separate local ventilation is being provided for the station platforms, with a view to keeping them as fresh and pleasant as possible. For this purpose a special 5-foot diameter shaft has been sunk at each station, though which air is injected into a duct which runs below the station platform, as shown in one of the drawings. Five branches from the duct are provided at equidistant points along the platform, rising to grids 7 ft. 3 in. above foot level, and the grids will be provided with louvres directing the air outward and somewhat downward across the platform.

Yet another ventilating system is provided at most of the stations, comprising an exhauster fan taking its suction from the machinery space of the escalators, from lavatories where provided, and from other points from which contaminated air might conceivably pass into the public areas. These plants and equipment are being supplied by Davidson & Co. Ltd. Direct current motors with Brookhirst starters will be installed.

# CURRENT PRACTICE.

[ 625. 232 (.42) ]

## Buffet car for the Leeds-Newcastle service, London North Eastern Railway.

Following the success of the buffet car trains which were introduced on the accelerated King's Cross-Cambridge service in May of last year, the London & North Eastern Railway Company has now introduced a larger and improved type of car for use between Leeds and Newcastle.

Fig. 1.

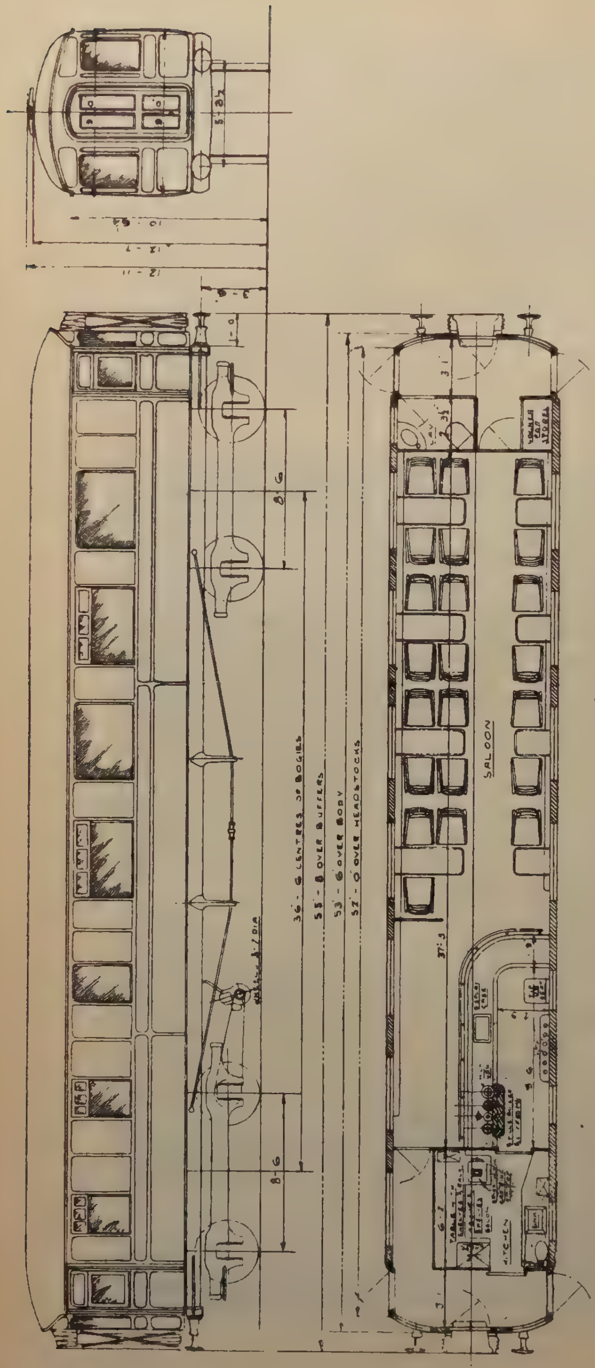

Fig. 2.

The car provides the traveller with all the amenities expected in an up-to-date café and in it the traveller can obtain a light meal, a snack, or other light refreshments.

The vehicle is of the saloon type and is provided with large windows and end doors only. The layout of the vehicle is shewn on the accompanying diagram. The saloon is 37 ft. 4 in. long, and has seats and tables for 22 passengers. A counter 11 ft. 3 in. long is arranged at one end of the saloon, together with a kitchen where light meals may be prepared. A lavatory and a store cupboard are provided at the opposite end of the saloon.

The interior of the saloon is decorated in mottled blue Rexine below the waist and gold Rexine relieved by royal blue mouldings above. The roof and spandrels are covered in cream Rexine, the floor being covered with blue marbled Korkoid having a 9-inch wide pearl grey border. Light blue pleated curtains are fitted over each window in the saloon and these are of double-sided Rexine.

The doors leading into the saloon are covered with gold Rexine and are provided with a diamond-shaped window and a chromium-plated handrail. The net racks and other metal fittings in the saloon are also chronium-plated.

The electric lighting of the saloon is provided by six 60-watt opal lamps in chromium fittings arranged down the centre of the roof.

Special chromium-plated tubular chairs have been designed for use with this saloon and they are upholstered in blue Rexine. The tables are fitted centrally with the large windows, the tops being covered with black Korkoid bound round the edges with a chromium band.

Adequate ventilation is ensured by the provision of sliding shutter ventilators over four of the body-side windows, together with an extractor fan and torpedo ventilators in the roof.

A large counter is provided, access

to which is by a sliding door from the kitchen. The counter top is covered with black Korkoid and the front is fitted with a chromium-plated hand rail and foot rail. A fixed showcase is also fitted on the counter. Under the counter is accommodation for bottled beers, aerated water, spirits, ice cream, cutlery and crockery. A rack is also provided on the body side for wines, spirits and liqueurs.

One of the most important features of the car equipment is the installation of a standard set of apparatus for the service of tea, coffee and milk, supplied by Messrs, W. M. Still & Son. The set comprises an automatic gas-heated boiler from which a supply of hot water is derived for the operation of a special coffee infuser. This by way of a three-way valve supplies coffee to either of two urns. The urns are arranged so that coffee may be drawn from one whilst further supplies are being passed to the other.

The boiler supplies hot water for making tea and for washing-up purposes, whilst steam is utilised for heating the milk urn.

It has not been found possible on previous cars to provide an equipment of this type but by an ingenious arrangement of feed control valve and auxiliary tank the same service can be obtained as from an ordinary buffet, freshly made tea and coffee being instantly available to meet any demand.

The kitchen, the entrance to which is in the vestibule, is approximately 6 feet square and is finished up to the waist in teak paint with white enamel above; the floor is covered with Korkoid. The fittings in the kitchen include a toaster and grill, gas ring, ice chest, water filter complete with glass reservoir, sink with hot and cold water supply and the usual tables, cupboards, racks, etc. A 70-gallon water tank is fitted in the roof.

The whole of the work has been carried out at the York Works of the London & North Eastern Railway Company, to the designs of Mr. H. N. Gresley, the Chief Mechanical Engineer.

# MISCELLANEOUS INFORMATION.

[ 621. 135 2 & 656. 284 ]

## 1. — Fractures in railroad tires.

*(The Metallurgist, Supplement to The Engineer.)*

In the exceptionally severe winter of 1928-29 an unusually large number of fractures occurred in locomotive and tender tires on the Austrian railways. An investigation into the cause of these failures is described by Pohl.* It was suspected that the increased mortality might be connected with the known diminution of the toughness of carbon steels at low temperatures. The results of the investigation led, however, to the conclusion that whilst the abnormally low temperatures had no doubt contributed to the failures, the main causes were defects in the tires themselves. A number of the fractured tires were subjected to metallurgical and mechanical tests. All the fractures had the appearance of having been caused by shock, without preceding deformation. No evidence of fatigue failure with its characteristic gradual spreading of cracks was observed.

Mechanical tests on test pieces from near the fractures gave the results shown in the accompanying table:

| Tire. | Yield stress, kgr./mm.² (*Engl. tons per in²*). | Maximum stress, kgr./mm.² (*Engl. tons per in²*). | Reduction of area, per cent. | Elongation ($l = 10\,d$), per cent. | Impact test, (1) Kg.-M/cm.² (*Foot-lb. per in²*). | Phosphorus, per cent |
|---|---|---|---|---|---|---|
| 1. . . . . . . . | 52.2 (*33.1*) | 95.1 (*60.4*) | 5.8 | 6.0 | 1.06 (*49.5*) | 0.054 |
| 2. . . . . . . . | — | 97.3 (*61.8*) | 22.5 | 10.0 | 1.45 (*67.7*) | 0.079 |
| 3. . . . . . . . | 49.0 (*31.1*) | 85 7 (*54.4*) | 25.6 | 14.0 | 1.19 (*55.6*) | 0.079 |
| 4. . . . . . . . | 52.7 (*33.5*) | 94.9 (*60.3*) | 18.6 | 10.0 | 1.38 (*64.4*) | 0.067 |
| 5. . . . . . . . | 45.9 (*29.1*) | 85.5 (*54.3*) | 23.9 | 14.0 | 1.38 (*64.4*) | 0.067 |
| 6. . . . . . . . | 49.0 (*31.1*) | 93.1 (*59.1*) | — | — | 1.43 (*66.8*) | 0.044 |
| 7. . . . . . . . | 48.5 (*30.8*) | 79.0 (*50.1*) | 25.4 | 11.0 | 1.34 (*62.6*) | 0.075 |
| 8. . . . . . . . | — | 85.1 (*54.0*) | 24.0 | 13.0 | 1.20 (*56.0*) | 0.047 |

(1) At room temperature with a hammer giving an energy of blow of 75 Kg.-M (542 ft.-lb.), using a Charpy test piece of 30 mm. by 30 mm. (1 3/16 in. × 1 3/16 in.) section with round bottom notch, 4 mm. (5/32 inch) diameter.

Hardness calculated from the ultimate stress values was higher than is admissible under existing specifications of the Austrian railways, but notch bar toughness was not lower than usual for steels commonly used for tires. Investigation into the effect of low temperature on these steels, which had been intended, was abandoned in view of the results of the macro and micro-examination described below, and of the fact that a further series of impact tests at ordinary temperature using a Mesnager test piece gave very irregular results.

Fractures generally were characterised by longitudinal cracks running perpendicular to the main fracture, i. e., in the direction of the tire plane, as shown in figure 1, and in close proximity to the point of origin of the main fracture. Without exception, these subsidiary cracks followed the gain boundaries of a pronounced dendritic crystallisation, as indicated in figure 2, or the course of segregates of non-metallic inclusions associated with gas cavities, as shown in

(1) *Stahl und Eisen*, 2 June 1932.

figure 3, which also shows the dendritic regions in the steel. The remarkable length of individual dendrities in relation to the tire section is evident in figure 4.

In discussing the ill effects of such a macrostructure, Pohl refers to what he terms the « quasi-isotropy » of a crystalline structure of uniform texture and suitable grain size. Under such conditions individual crystals unfavourably situated (or oriented) in regard to superimposed stress, by yielding slightly can bring neighbouring crystals into co-operation. The quasi-isotropy acts accordingly to distribute stress uniformly. The structures indicated in figure 2, 3 and 4, showed that there was no question of quasi-isotropy, and therefore of uniform stress

Fig. 1. — Typical appearance of main fractures.

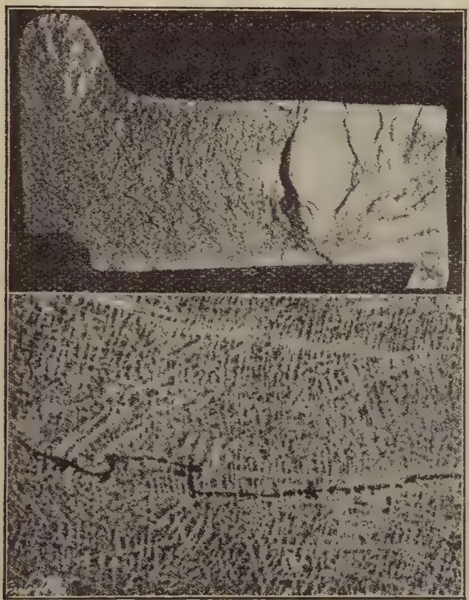

Fig. 2. — Crack formation along dendrite boundaries.

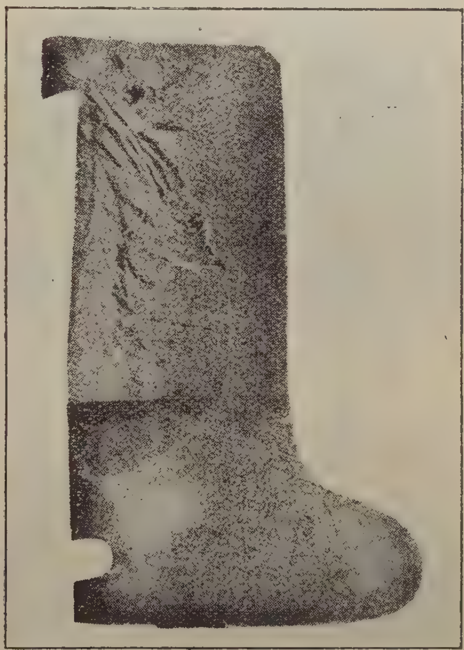

Fig. 3. — Crack formation between non-metallic enclosures associated with gas cavities.

distribution in the material of the tires in question. Coarse primary crystallisation such as was present, by reason of the attendant « coreing » effects in the crystals and the trapping of non-metallic impurities and gas bubbles between the dendritic arms, has the further grave disadvantage of grain boundary weakness. The presence of this coarse structure with its attendant evils referred to above, by leading to the formation of local fissures under stress, was concluded to be the main cause of the transverse failures of the tires. The low temperature no doubt aggravated the ill effects by impairing the toughness of the material, and by accentuating the impact stresses on the tires through the track and rolling stock becoming frost-bound.

Dendrite formation such as was found in the present tires occurs during the primary crystallisation of the molten steel. Metallurgical knowledge to-day enables it to be controlled between limits by foundry technique, but not prevented. In most rolled and forged products the primary structure of the ingot is broken up and largely obliterated through hot working and heat treat-

ment. In the commonly used methods of production of tires, however, from relatively small truncated cone-shaped ingots, or cheese-shaped slices parted from rectangular ingots, the amount of mechanical working is comparatively

Fig. 4. — Dendrite formation.

small and insufficient to destroy a coarse structure. Even where partings from forged blooms are used as tire blanks, the effect of the additional working on the primary structure is hardly noticeable. Application of further working in an attempt completely to destroy a coarse primary structure would make the cost of production prohibitive. The method, common in Germany, of using discs parted from ingots about 2 m. (6 ft. 6 in.) long offers the advantage that piping and larger gas cavities, if present, are readily apparent on the cut faces, but has the disadvantage of greater segregation in the larger ingot.

The ill effects attendant upon the retention of primary structure in tires can, however, be lessened by employing steel of high purity and cleanliness. In this connection Pohl criticises the method of controlling composition by a single test sample taken from the bath or ladle before pouring. Reactions between molten steel and slag may well occur during pouring, and alter the purity and quality of the metal. He advocates that at least a sample should be taken before pouring the last ingot, and the exclusion of that ingot ensured if the analysis of the sample is unsatisfactory. Further, to guard against tires in which hardness is undesirably high or irregular, in spite of satisfactory results from the melt analysis, piece by piece testing for Brinell hardness should be done. There is no fundamental objection against high hardness in tires, provided it is uniform throughout the material. The ill effects on toughness of too high a finishing temperature in rolling may be eliminated by a normalising treatment which should be followed by annealing, at a temperature sufficiently high to remove internal strains which may result from the air cooling in normalising. All these precautions have been insisted upon, Pohl states, in the case of tires supplied to the Austrian railways for some time past, with beneficial results.

[ 621 .331 (.45) ]

## 2. — Travelling sub-stations with mercury rectifiers, Italian State Railways.

*(The Railway Engineer.)*

As is well known, the Italian State Railways have a number of travelling sub-stations which are used on the extensive network of 3-phase (3 600 volts, 16 2/3 cycles) electrified lines. They are used as required to supplement fixed sub-stations when demands on certain sections of line are temporarily increased beyond the capacity of the latter, and also to replace them altogether in case of breakdown.

Recently, in view of the extension of electrification in Italy on the 3 000-volt D.C. system two new travelling sub-stations, built by Brown,

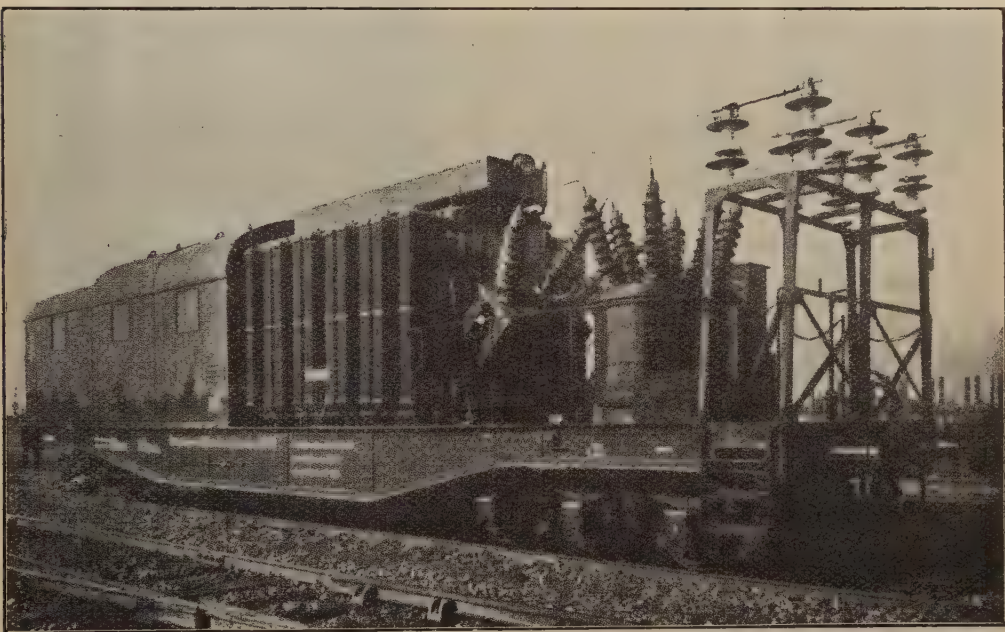

Fig. 1. — New portable travelling D. C. sub-station, Italian State Railways.

Boveri & Company have been put into service. The use of rotary converters would have rendered the problem practically impossible of solution, so investigations obviously lay in the direction of the comparatively compact static mercury-arc rectifier. The accompanying photographic reproduction and drawings indicate the essential features of the new portable sub-stations, whose total weight is 74 tons distributed over 5 axles.

The equipment includes a transformer for 60 000-volt, 45-cycle current, and a 2 000-kw. mercury-arc rectifier feeding direct current at 2 900 volts to the contact wire. Permissible overloads are 20 % for 2 hours, 50 % for one hour, and 100 % for 2 minutes. A closed cir-

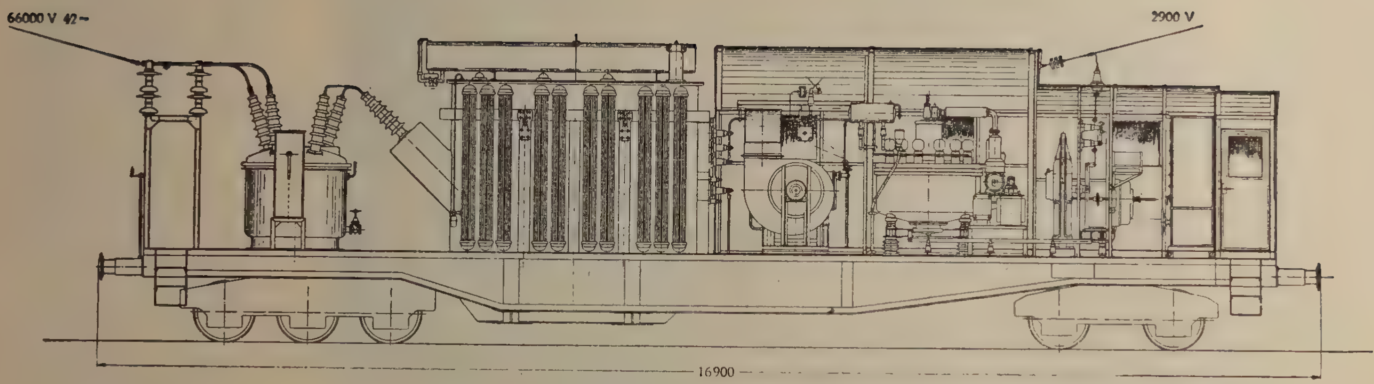


Fig. 2. — General arrangement drawing.

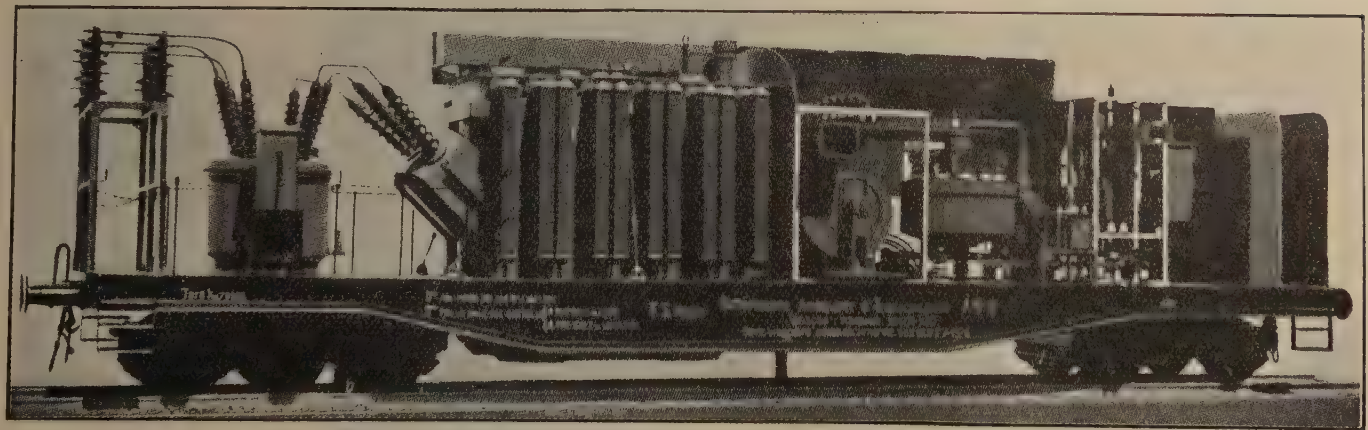

Fig. 3. — Portable travelling D. C. sub-station, Italian State Railways.

cuit cooling set and high-vacuum pump are also included.

The high-tension apparatus and the transformer are arranged in the open air; the rectifier, the cooling devices, and the apparatus for the direct current are arranged under cover in a special cabin.

The rectifier is carried on a frame which is insulated from the truck frame by means of special wooden insulators. The vibrations of the rectifier-cylinder are lessened by means of spring suspension.

The electric connections between the rectifier, the transformer, the bus bars, etc., consist of flexible cables and connecting members. The connection between the cooler group and the rectifier cylinder consists of rubber tubes. The cooling set comprises two laminated radiators cooled by an air current generated by a blower fan.

The quick-break switch and all the other direct-current apparatus (resistances for the earth test, contacts, relays) are mounted on steel frames. A transmitting insulator and a collecting insulator are arranged on the roof of the truck to permit of electric connection between the substation and the contact line.

In the rear part of the truck is the switchboard.

As the rectifier, the cooler pumps, the ignition devices, etc., are under tension, the space which they occupy is completely insulated from the driver's (controller's) cabin. Any necessary inspection can be made only after the current has been switched off. The production of the rectifier on the primary side is ensured by means of a three-pole oil switch and on the feeder side by a rapid action switch which is provided with a maximum relay. If a short circuit occurs on the line it opens the circuit at once. The oil switch, however, acts more slowly.

On the direct current side is arranged a current-return relay, which functions when the reaction reaches 10 % of the normal. This relay ensures that the rectifier is put out of action in case of internal short circuits.

The sub-station is designed for automatic working.

# NEW BOOKS AND PUBLICATIONS.

[ 385. (09.(.62) ]

WIENER (Lionel), Professor at the University of Brussels. — **L'Egypte et ses Chemins de fer (Egypt and its Railways)**, a work published under the patronage of H. M. King Fuad the Ist on the occasion of the XIIth Session of the International Railway Congress Association (Cairo 1933). One volume (11 × 7 inches), of 666 pages with many maps, illustrations and colour engravings. Brussels, published by Messrs. Weissenbruch, Printers, 49, rue du Poinçon.

The delegates travelling to the Congress in Cairo are rightly anxious to collect information on the country in which the next meetings of the Congress will be held, and especially upon its transportation facilities. If their interest is primarily concentrated on the questions on the agenda, their attention is also given to the various aspects of railway operation in the countries they are to pass through or visit. Each desires to form an idea of the climatic conditions and of the orography, the hydrography and the control of the waterways as well as of the natural mineral resources, and is anxious to know something about the density and distribution of the population, the situation relatively to the surrounding countries, and relatively to the great international lines of communication, all these being factors which influence the organisation of the railway system. By examining the solutions adopted and the methods employed, the reader prepares himself so as to be able to make useful comparisons.

The Organising Committee of the Congress, the initiative of which must be admired, has been particularly well inspired in presenting to the delegates the fine work by Mr. Wiener. We have here a happy example of a book appearing just at the right moment. The example is even more fortunate, as it fills a gap, as the saying is, for as the author points out in the introduction, whilst Egypt has been studied from all points of view, it is surprising that there is no work in existence on its railways.

We may also point out that by a happy coincidence the very author for the work was available ; in fact the work appeared to have been reserved for him to do. If as it does, this work pleases us, if it will please all who will possess it, this is not surprising. Mr. Wiener owed it to himself to see that this was so. He has devoted himself for many years to the study of the many problems raised in the construction and operation of railways, whether of a technical, economic, or financial nature. He has enriched the literature on the subject by many works, some of a general character, and others more especially directed to overseas railways. Without giving the full list, which would be too long, some of the subjects he has analysed may be quoted : gauges and gradients of railways, locomotives, and especially articulated locomotives, speeds of trains, the formation and orientation of railway systems, detailed monographs of railways in Europe, Asia, South America, and Africa. *Egypt and its Railways* may be considered as a supplement, although a largely developed one of his recent work : *The Colonial Railways of Africa.*

It is impossible to review in a few sentences a work of 666 pages. We must be satisfied by saying that the reader will find in it all needed information on the railways of Egypt and the Sudan, both those belonging to the State and those of the private Companies, whether standard or narrow gauge, main lines or light railways. The history of the rail-

ways, their construction and development, intimately bound up with the political life of the country, is not the least attractive part of this book. The technical characteristics of the lines, the permanent way equipment, the principal structures, rolling stock, nature and magnitude of the traffic, financial results, and the future prospects are dealt with as a whole in a way that could not be bettered. To bring this out clearly, the author has broadly sketched in the geography of Egypt and described in detail the course of the Nile, this longest river in the world (6 000 km. = 3 730 miles) which, flowing out of Lake Victoria, eventually after many wanderings, comes to exercise its fecund and civilising influence on the celebrated valley. The illustration of the work, the composition of which shows a fine sense of selection, enhances, by its taste and variety, the appearance of the book so magnificently printed by Messrs. Weissenbruch, of Brussels.

Printed facing the title page, is found a fine portrait of H. M. King Fuad I, « whose enlightened care and great encouragement have enabled this work to be published » and later on, a portrait of Mohammed Ali whose large mindedness appreciated the usefulness of railways from their beginning. Two other engravings remind us of those great figures : Robert and George Stephenson, whose memory is unseparable from the origin of railways and in whose name the contract for the construction of the first railway in Egypt was signed. Artistic photographs, pencil and coloured drawings reproduce views of the country, buildings, stations, and modern workshops, signalling plant, and various rolling stock and fixed equipment.

Many clear and well engraved maps illustrating the layout of the railway system assist the reader in finding his way. They will certainly be much appreciated by all the delegates to the Cairo Congress.

We would compliment the Author and the Organising Committee for an instructive, agreeable and elegant book, which will assist in passing the journey pleasantly, and will ultimately find a deserved place in libraries of scientific literature. E. M.

*January, 1933.*

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[ **656. 23** ]

KUTTNER (F., Dr. œc.). — **Die Selbstkosten der Verkehrsbetriebe bei schwankendem Beschäftigungsgrad.** — Eine betriebswissenschaftsliche Studie (**The influence of traffic variations upon the cost of operating transport services.** — A study of scientific operation). — 1 volume ($8\frac{1}{4} \times 6$ inches) of 142 pages with 60 figures. — 1932, Berlin W. 9, Voss-Strasse, 6. — Published by the « Verkehrswissenschaftliche Lehrmittelgesellschaft m. b. H. bei der Deutschen Reichsbahn. (Price, paperbound : 7.25 Rm. — A reduction is made to the staff of the Reichsbahn.)

Transportation has always been the section of the economic structure to be affected to the greatest extent by variations in human activity. For some twenty years past attention has been directed to making thorough investigations of the effect of varying output on the cost of industrial operations, and the conclusions that it was possible to arrive at concerning methods of calculation, selling price policy, and other important factors in production, have shown the practical value of studies, that were in the main of a scientific character. In the transportation field, however, practically nothing has been done to explore these important and essential interrelations.

It follows that the thorough treatment of these questions, by Dr. Kuttner, con-

stitutes the first step towards filling this important gap. He investigates the nature of the individual variations in activity after an exhaustive study of the literature on the subject, and with the aid of a great volume of statistical material drawn from some 50 000 records of the most varied classes of transport, tramways, rapid transit system, narrow gauge lines, and railway networks.

The characteristics of variations in traffic frequency are illustrated by 60 illustrations and diagrams, from which it is possible to grasp the laws governing these changes, both amongst themselves and from season to season, from week to week and from day to day.

The second part of the book deals with the effect of varying traffic upon the several kinds of operating costs, utilising some interesting new methods suggested by the author. Insight is obtained into the elasticity of these various kinds of costs in the face of frequency variations both from the financial point of view and from that of time response, and it can be seen how far operating policy can be directed towards counteracting particularly objectionable effects. The final chapter is devoted to throwing some light upon the close relation which exists between the problem as a whole and the rates policy.

The increasing magnitude of transport operations renders it continually more difficult to obtain a proper appreciation of the relation between the economic factors, especially in that branch which is concerned with the working out of costs. For this reason a comprehensive review of the latter field will be particularly valuable to many heads of transport undertakings, business men and technical experts.

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[ 62. (03 ]

**Hoyer-Kreuter Technologisches Wörterbuch. — Hoyer-Kreuter Technological Dictionary. — Dictionnaire technologique Hoyer-Kreuter.** — Sixth edition, completely revised, published by Dr. Ing. E. h. A. Schlomann. — Vol. I : Deutsch-English-Französisch. — Vol. II : English-German-French. — Vol. III : Français-Allemand-Anglais. — 3 volumes (8 × 11 inches) of about 800 pages each. — 1932, Berlin W. 9, Julius Springer, Publisher. (Price : Vols. I and II, 78 Rm. each; Vol. III : to be published shortly.)

This is the 6th and completely revised edition of the Hoyer-Kreuter technological dictionay in three languages.

The successive editions of this work, the 5th of which came out at the beginning of the century (1904), have shown the practical interest manifested in its publication. Since 1904, however, technical vocabularies have been greatly developed in every field so that a thorough revision of the whole work was insispensable.

In the many technical dictionaries dealing specifically with one or other subject which have recently appeared, by reason of their nature, general words and expressions used in technical language are often not given, while the ordinary dictionaries of a language do not always give the meanings, at least in a sufficiently precise way, of technological words; consequently, besides the special technical dictionaries, very valuable in themselves, it is necessary to have a general technological dictionary. This need is filled by the work with which we are dealing, and it is in this direction that the work in question has been completed and revised.

Among the special dictionaries to which we have alluded, the collection of illustrated dictionaries in 6 languages edited by Dr. A. Schlomann is in the first rank. Dr. Schlomann was entrusted

with the task of revising the Hoyer-Kreuter technological dictionary. He has completed this work with the same method and precision manifested throughout the illustrated dictionaries in 6 languages.

The technological dictionary completes the special technical dictionaries of this type; it contains words and expressions met with in industry, commerce, the applied sciences, general engineering, building, transportation, agriculture, legislation, international law, etc.

This 6th edition consequently meets a real need and will certainly be received with the same interest as the previous editions.

A. C.

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656. 222.1 ]

RIBEIRO (G.), B. A., M. A. Am. Soc. C. E., Chief Constructional Engineer of the Great Western Railway of Brazil, and HULME (W.), A. M. I. Mech. E., M. I. Loco. E., formerly Assistant to the Chief Mechanical Engineer of this Railway Company. — **Ribeiro's train-rating diagrams.** — 6 tables and instruction book. Published by the *Locomotive Publishing Co. Ltd.*, 3, Amen Corner, London, E. C. 4. (Price : 5 sh. net.)

This publication includes a series of diagrams for determining the factors involved in calculations in connection with train rating; three of the diagrams are given in metric measures, and the three others in English measures.

Train loads can easily be calculated when the following factors are known : the tractive effort of the locomotive, the total resistance of the locomotive and tender, the specific resistance of the rake. Diagram No. 1 gives the actual resistances of wagons under different hypotheses of load, of train speed, of the profile of the line for both narrow and standard gauge. By means of Diagram No. 2 the total resistance of the locomotive and tender, taking into account the number of and the weight on the driving and carrying pairs of wheels, can be determined. Diagram No. 3 is used for calculating the tractive power of the locomotives, whether saturated or superheated. The instruction book gives the formulæ used in drawing up these diagrams, as well as instructions on the method of using these latter.

We wish to call the attention of the traction and operating services who have to draw up train rating tables, to this interesting publication; these diagrams will also be of use to them in studying problems connected with these subjects : the calculation of virtual distances, comparison between different types of locomotives from the point of view of tractive power, investigation into the cost of hauling trains, etc.

A. C.

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[ 625. 5 ]

MAFFEZZOLI (A.), Professor at the Engineering School of Naples. — **Elementi di Calcolo delle Funivie per servizio pubblico (Elements entering into the calculation of aerial railways for public transport services).** — One volume (7 × 10 inches) of 240 pages, with 78 figures. — 1931, Naples, Libreria Scientifica ed Industriale de B. Pellerano. (Price : 30 lire.)

The utilisation of the aerial funicular railway for transporting passengers, by supporting and hauling wire ropes, is a relatively new method of transport; it was used in two or three cases between 1908 and 1914. The war interrupted the

construction of new installations for public services, but very important applications were made for strategic purposes in both Austria and Italy, in the Alps. Since then several new installations have been completed in Italy, Austria, and Bavaria.

The work of Professor Maffezzoli sets out the present state of technical knowledge on aerial funicular passenger railways. It begins by a short historical review, and then sets out the principles of the different systems of funicular railways; one chapter is devoted to the thory of the wire rope. Successive chapters deal with the study of the curve taken by the carrying rope, the calculation of this latter, the study of the profile of the line, the forces acting on the hauling cable, the calculation of the counterbalance weights, the determination of the power required, the verification of the safety of the installations, the construction of the rolling stock, the calculation of the pylons and the building of stations.

The work ends with the Italian technical regulations relating to the matter, and by a description of the constructional features of the principal installations recently completed.

The work includes many numerical tables, and examples of calculations; consequently it is a theoretical and practical manual which will be of use not only to engineering students but also to engineers having to deal with problems in connection with transport by aerial railways.

A. C.

## CORRIGENDUM.

### Bulletin, November 1932.

**Report by Mr. E. DÄHNICK (Question VI, Cairo Congress, 1933).**

Page 2082, 2nd column, the *5th paragraph is to be replaced by the following:*

« As a new constructional method, welding has also, in the case of the 25 carriages and 25 luggage vans for fast passenger trains, led to a saving in weight of 5 tons for the AB*d* carriage, i. e. 10 % relatively to the former all-metal carriages, and of 3 tons compared with the small luggage van, or 9 % as compared with the old wood types. »

Page 2106, 2nd column, 14th and 15th lines :

*Instead of :* « No reduction in weight... »

*Read :* « As stated previously, welding has resulted in a saving in weight of up to 10 % as compared with the former all-steel construction. »

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